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MISCELLANEOUS PAPER NO. 4-931

# XC-142A AIRCRAFT FLIGHT TESTS LANDING STRIP EVALUATIONS

by

W. B. Fenwick

October 1967

Sponsored by

Air Force Systems Command
Aeronautical Systems Division
Wright-Patterson AFB, Ohio





Conducted by

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

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13. ABSTRACT

Tests were conducted at four sites in California to determine the capability of the XC-142A aircraft to operate on or hover over unprepared or expediently surfaced landing strips. Soil data were collected from eight sites, but only four of the sites were used for subsequent flight tests. Results of the tests indicated that the overall performance of the XC-142A was good. Rutting was moderate at every test site except one. However, results also indicated that the flotation characteristics of the nose gear should be increased, and means should be provided to prevent future derimming as occurred at one of the test sites. Additional study of the relation of wing angle versus soil recirculation is also needed. After the flight tests had been completed, a mineralogical analysis of soil samples from the four sites was made. Results of the analysis are presented in Appendix A.

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| | ROLE | WT | ROLE | WT | ROLE | WT |
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| Ground flotation | | | | | | |
| Landing strips | | | | | | |
| Soils--Analysis | | | | | | |
| XC-142A aircraft | | | | | | |

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## Foreword

The U. S. Army Engineer Waterways Experiment Station (WES) was requested by the Aeronautical Systems Division, Air Force Systems Command, U. S. Air Force, Wright-Patterson Air Force Base, Ohio, in a letter dated 20 May 1966, to determine surface roughness and other soil characteristics at test sites to be used in connection with flight tests of the XC-142A aircraft. Responsibility for the overall prosecution of this investigation was assigned to the Tri-Service Test Force, Edwards AFB, California. The results of this investigation were furnished the sponsor in Memoranda for Record, subject "XC-142A Aircraft Flight Tests, 2 May-10 June 1966," dated 2 August 1966, and "Soils Tests Conducted After XC-142A Aircraft Flight Tests, 20-22 September 1966," dated 7 December 1966.

The field investigations were conducted by personnel of the Flexible Pavement Branch, Soils Division, WES, at and near Edwards AFB during the periods 2 May-10 June 1966 and 20-22 September 1966. Engineers actively engaged in the planning, testing, analyzing, and reporting phases of the studies were Messrs. W. J. Turnbull, Division Chief, A. A. Maxwell, R. G. Ahlvin, D. N. Brown, C. D. Burns, W. B. Fenwick, R. H. Grau, and T. D. White. Messrs. R. W. Patrick, T. G. Habeeb, and R. T. Sullivan, technicians, assisted in procuring the data. The mineralogical analysis of the soil was performed by Mrs. K. Mather and Mr. W. I. Luke of the Concrete Division, WES, and the appendix was excerpted from their report. This report was prepared by Mr. Fenwick.

Director of the WES during the investigation and preparation of this report was COL John R. Oswalt, Jr., CE. Technical Director was Mr. J. B. Tiffany.

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## Conversion Factors, British to Metric Units of Measurement

British units of measurement used in this report can be converted to metric units as follows:

| Multiply | By | To Obtain |
|---|---|---|
| inches | 2.54 | centimeters |
| pounds | 907.185 | kilograms |
| pounds per square inch | 0.070307 | kilograms per square centimeter |
| pounds per cubic foot | 16.0185 | kilograms per cubic meter |

## Summary

Tests were conducted at four sites in California to determine the capability of the XC-142A aircraft to operate on or hover over unprepared or expediently surfaced landing strips. Soil data were collected from eight sites, but only four of the sites were used for subsequent flight tests.

Results of the tests indicated that the overall performance of the XC-142A was good. Rutting was moderate at every test site except one. However, results also indicated that the flotation characteristics of the nose gear should be increased, and means should be provided to prevent future derimming as occurred at one of the test sites. Additional study of the relation of wing angle versus soil recirculation is also needed.

After the flight tests had been completed, a mineralogical analysis of soil samples from the four sites was made. Results of the analysis are presented in Appendix A.

# XC-142A AIRCRAFT FLIGHT TESTS; LANDING STRIP EVALUATIONS

## Introduction

1. This report presents the results of field investigations of sites for aircraft flight tests. The investigations were concerned with the capability of the XC-142A aircraft to operate on or hover over unprepared or expediently surfaced landing strips. The report describes the test aircraft, purpose and scope of the investigation, and the test sites selected, which were located at or near Edwards AFB, California. Soil data are presented herein for eight test sites although, in the subsequent flight tests, only four were actually used. Observations of the test flight operations and the posttest condition of the four sites used in the study are also presented.

## Test Aircraft

2. The XC-142A is a four-engine, tilt-wing, V/STOL transport aircraft having a gross weight of approximately 40,000 lb.* The dual main landing-gear tires are 11.00-12, 8-ply tires inflated to 45 psi. The dual nose-gear tires are 8.50-10, 10-ply tires inflated to 72 psi. The higher tire pressure and the comparatively high percentage (26.4 percent) of weight distributed to the nose gear make this gear considerably more severe than the main gear from a flotation standpoint.

## Purpose and Scope of Investigation

3. The U. S. Army Engineer Waterways Experiment Station (WES) participated, during May, June, and September 1966, in a program of tests conducted to determine the capability of the XC-142A aircraft to operate from remote sites. The original test program included aircraft operations

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* A table of factors for converting British units of measurement to metric units is presented on page ix.

from eight different sites with various soil, surface roughness, and vegetation conditions, but due to scheduling difficulties, actual aircraft operations were performed at only four sites. The WES's part in the test program was to obtain surface roughness data in the form of level profiles, and pertinent soil data for the eight sites at the time of the flight tests. Data are presented herein for all eight test sites, although only the last four sites for which data are presented were used for flight tests. All soil classification was accomplished according to MIL-STD-619A, "Unified Soil Classification System for Roads, Airfields, Embankments, and Foundations."

## Test Sites and Data Obtained

### Sites not used for aircraft operation

4. Since all required soil data had already been obtained for these sites, these data are included in this report for possible future use.

5. Twenty-nine Palms, Calif. Two landing-mat-surfaced runways at the Marine Corps Air Station (MCAS) near Twenty-nine Palms were proposed test sites. The runways, one of pierced-steel landing mat (M6) and the other of M9M1 landing mat, are shown in photographs 1 and 2, respectively. Center-line profiles are shown in plate 1, and soil classification data in plate 2. With the exception of classification data, no soil data were obtained at this site since soil strength was not pertinent for the landing-mat-surfaced runways.

6. Point Mugu, Calif. (north runway). A sod-covered site (photograph 3) adjacent to the N-S runway of Point Mugu Naval Air Station (NAS) was originally included in this study but later abandoned for aircraft test operations due to anticipated interference with the large volume of traffic on the N-S runway. Surface roughness and soil classification data are shown in plates 3 and 4, respectively. The average water content in the top 3 in. of soil was 2.2 percent, and in the 6- to 9-in.-depth range it was 7.8 percent. The average dry density in the top 6 to 8 in. was 95.4 pcf, as obtained with the Nuclear-Chicago moisture density equipment (photograph 4). The average CBR at the surface was about 6 to 7; at a depth of 2 in., the average CBR was about 15.

7. Edwards AFB, Calif. CV-7 (north) runway. Data were also obtained from a hillside site near Edwards AFB. Surface roughness and soil classification data are shown in plates 5 and 6, respectively. A general view and a closeup view of the site are shown in photographs 5 and 6, respectively. The average water contents in the 0- to 3- and 6- to 9-in.-depth ranges were 0.8 and 1.7 percent, respectively; the average dry density of the 0- to 3-in. layer was 101.4 pcf. The following tabulation shows the CBR values obtained.*

| Test Runway | CBR at Depths, in. | | | | | | |
|---|---|---|---|---|---|---|---|
| Sta | 0 | 2 | 4 | 6 | 8 | 10 | 12 |
| 0+00 | 0.5 | 1.7 | 12.0 | 18+ | -- | -- | -- |
| 1+00 | 0.5 | 1.7 | 18.0 | 18+ | -- | -- | -- |
| 2+00 | 0.5 | 0.5 | 6.6 | 12 | 12 | 16 | 18+ |
| 3+00 | 0.5 | 0.5 | 12.0 | 18+ | -- | -- | -- |
| 4+00 | 0.5 | 1.0 | 14.0 | 18+ | -- | -- | -- |
| 5+00 | 0.5 | 1.0 | 8.0 | 18+ | -- | -- | -- |
| 6+00 | 0.5 | 0.5 | 16.0 | 18+ | -- | -- | -- |

8. Edwards AFB, Calif. TAC-2 (west) runway. Data were obtained from a site in the desert foothills about eight miles west of Edwards AFB. Surface roughness and soil classification data are shown in plates 7 and 8, respectively. A general view and a closeup view of this runway are shown in photographs 7 and 8, respectively. The average water contents in the 0- to 3- and 6- to 9-in.-depth ranges were 2.3 and 2.6 percent, respectively; the average dry density in the 0- to 3-in. layer was 96.4 pcf. The following tabulation shows the CBR values obtained.

| Test Runway | CBR at Depths, in. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sta | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 |
| 0+00 | 0.5 | 0.5 | 6.6 | 18+ | -- | -- | -- | -- | -- | -- |
| 1+00 | 0.5 | 1.0 | 11.0 | 18+ | -- | -- | -- | -- | -- | -- |
| 2+00 | 0.5 | 2.4 | 5.3 | 12 | 12 | 12 | 12 | 14 | 16 | 18+ |
| 3+00 | 0.5 | 1.0 | 5.3 | 14 | 18+ | -- | -- | -- | -- | -- |
| 4+00 | 0.5 | 1.7 | 9.3 | 18+ | -- | -- | -- | -- | -- | -- |

* All CBR values were obtained by conversion of the airfield index, which was measured with the airfield cone penetrometer.

Sites used for aircraft operation

9. Point Mugu, Calif. (south runway). A sod-covered strip adjacent to the east end of the E-W runway (photograph 9) was used for the XC-142A aircraft operations. Surface roughness and soil classification data for this site are shown in plates 9 and 10, respectively. The average water contents in the 0- to 3- and 6- to 9-in.-depth ranges were 0.4 and 0.6 percent, respectively; the average dry density was 97.6 pcf. The following tabulation shows the CBR values obtained.

| Test Runway Sta | CBR at Depth, in. | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 2 | 4 | 6 | 8 | 10 |
| 0+00 | 0.5 | 1.8 | 5.0 | 9.3 | 14 | 15+ |
| 1+00 | 0.5 | 2.8 | 7.3 | 8.0 | 12 | 15+ |
| 2+00 | 0.5 | 1.6 | 3.3 | 5.0 | 15+ | -- |
| 3+00 | 0.5 | 2.9 | 4.5 | 11.0 | 15+ | -- |
| 4+00 | 0.5 | 2.0 | 3.6 | 6.6 | 11 | 15+ |
| 5+00 | 0.5 | 3.2 | 6.6 | 12.0 | 15+ | -- |
| 6+00 | 0.5 | 3.2 | 7.7 | 15+ | -- | -- |
| 7+00 | 0.5 | [illegible] | 8.0 | 15+ | -- | -- |
| 8+00 | 0.5 | 2.7 | 9.3 | 15+ | -- | -- |
| 9+00 | 0.5 | 1.5 | 3.5 | 8.1 | 13 | 15+ |
| 10+00 | 0.5 | 2.3 | 4.5 | 6.6 | 14 | 15+ |

About 13 XC-142A aircraft operations were made at this site. On the fourth STOL landing (using maximum braking), the nose gear dug into the soil and was cocked fully to the left. The rut formed by the nose gear was approximately 16 in. deep, and the rut formed by the main gear was 1 to 2 in. deep. General views of the buried nose gear are shown in photographs 10 and 11. The aircraft made a vertical takeoff, as shown in photograph 12 (note cocked nose gear), and landed on the paved runway where it was learned that both nose-gear tires had been derimmed and were flat, as shown in photograph 13. When the nose gear received a substantial side load, such as when the gear was cocked or on a taxi turn, the lateral force pulled the tires from the rim, and the air escaped. This will probably be corrected by the use of tube-type tires, which is planned for the future. It is believed that the tires were flat before the nose gear dug in completely. In later tests, both nose-gear tires were again derimmed and went flat on a taxi turn, and as the turn was

continued, the aircraft was again immobilized when the wheel rims cut into the soil. With the exception of the two incidents described above, the operation proceeded without difficulty. The average rut depth was 2 to 3 in., as shown in photograph 14. Some sod was broken loose (photograph 15) but did not create a hazard to the aircraft.

10. Edwards AFB, Calif. (desert test site). A test site was selected in the desert near Edwards AFB. Surface roughness and soil classification data for the desert test site are shown in plates 11 and 12, respectively. The average water contents in the 0- to 3- and 6- to 9-in.-depth ranges were 1.4 and 3.0 percent, respectively; the average dry density was 92.8 pcf. The following tabulation shows the CBR values for the desert runway.

| Test Runway Sta | CBR at Depths, in. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 |
| 0+00 | 0.0 | 5.8 | 9.1 | 5.6 | 5.6 | 10.0 | 11.0 | 13.0 | 12.0 | 11.0 |
| 1+00 | 0.2 | 6.5 | 9.6 | 8.3 | 7.9 | 7.8 | 7.5 | 8.7 | 9.4 | 11.0 |
| 2+00 | 0.2 | 5.2 | 8.5 | 8.7 | 8.1 | 6.8 | 7.1 | 6.5 | 7.9 | 12.0 |
| 3+00 | 0.0 | 3.8 | 11.0 | 12.0 | 11.0 | 7.1 | 5.3 | 4.2 | 4.5 | 9.3 |

General views of the site before and after traffic are shown in photographs 16 and 17, respectively. It can be seen in the photographs that some vegetation and loose surface material were broken away. Photograph 18 shows the XC-142A aircraft making a landing at the desert test site. Average rut depths of about 1 to 2 in. were noted, as shown in photograph 19. No operating difficulties occurred at this site.

11. Edwards AFB, Calif. CV-7 (south) runway. The XC-142A aircraft was operated from a hillside site identified as the CV-7 (south) runway. These tests were not witnessed by WES personnel, but Tri-Service Test Force personnel reported rut depths of 1 to 2 in. Surface roughness and soil classification data for this site are shown in plates 13 and 14, respectively. The average water contents in the 0- to 3- and 6- to 9-in.-depth ranges were 0.9 and 1.1 percent, respectively. The average dry density of the 0- to 3-in. layer was 96.9 pcf. The following tabulation shows the CBR values for the CV-7 runway.

| Test Runway Sta | CBR at Depths, in. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 |
| 0+00 | 0.5 | 8.0 | 8.0 | 6.6 | 6.6 | 14 | 9.4 | 16.0 | 18+ | -- |
| 1+00 | 0.5 | 1.7 | 2.5 | 6.6 | 8.0 | 12 | 3.8 | 3.8 | 5.3 | 9.4 |
| 2+00 | 0.5 | 8.0 | 14.0 | 18.0 | 18.0 | 18 | 18.0 | 16.0 | 16.0 | 14.0 |
| 3+00 | 0.5 | 8.0 | 8.0 | 16.0 | 18.0 | 14 | 12.0 | 9.4 | 18+ | -- |
| 4+00 | 0.5 | 9.4 | 9.4 | 16.0 | 18+ | -- | -- | -- | -- | -- |
| 5+00 | 0.5 | 14.0 | 12.0 | 12.0 | 18.0 | 18 | 18.0 | 12.0 | 12.0 | 16.0 |
| 6+00 | 0.5 | 9.4 | 12.0 | 14.0 | 18+ | -- | -- | -- | -- | -- |

A general view and a closeup view of this test site are shown in photographs 20 and 21, respectively. Propeller damage caused by soil recirculation during operations from this site and/or the TAC-2 east runway is discussed later.

12. Edwards AFB, Calif. TAC-2 (east) runway. One STOL landing and one vertical takeoff were made at a site in the desert foothills referred to as the TAC-2 east runway. WES was informed that rut depths of about 1 in. were observed after the STOL landing. Surface roughness and soil classification data for this runway are shown in plates 15 and 16, respectively. The average water contents in the 0- to 3- and 6- to 9-in.-depth ranges were 1.7 and 1.9 percent, respectively. The average dry density of the 0- to 3-in. layer was 99.5 pcf. The CBR values for this site are tabulated below.

| Test Runway Sta | CBR at Depths, in. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 |
| 0+00 | 0.5 | 1.7 | 6.6 | 11.0 | 12.0 | 12.0 | 12.0 | 14.0 | 18.0 | 18+ |
| 1+00 | 0.5 | 1.7 | 5.3 | 8.0 | 11.0 | 8.0 | 9.4 | 8.0 | 6.6 | 6.6 |
| 2+00 | 0.5 | 1.7 | 6.6 | 18.0 | 18+ | -- | -- | -- | -- | -- |
| 3+00 | 0.5 | 1.7 | 5.3 | 11.0 | 8.0 | 9.4 | 8.0 | 9.4 | 9.4 | 6.6 |
| 4+00 | 0.5 | 1.7 | 11.0 | 12.0 | 12.0 | 12.0 | 12.0 | 16.0 | 14.0 | 14.0 |
| 5+00 | 0.5 | 1.7 | 8.0 | 18+ | -- | -- | -- | -- | -- | -- |

A general view and a closeup view of the TAC-2 runway are shown in photographs 22 and 23, respectively. Propeller damage caused by soil recirculation during operations from the CV-7 south runway and/or this site is discussed below.

## Soil Recirculation

13. Eight takeoffs and eight landings were made at the CV-7 south runway with a wing angle of 25 deg (STOL). One STOL landing (wing angle 35 deg) and one vertical takeoff were made at the TAC-2 east runway. Examination of the propellers after these operations showed that severe erosion had occurred on the leading edges as a result of airborne soil particles.

14. In an attempt to determine the cause of the propeller damage mentioned above, a petrographic analysis was performed on surface soil samples from the CV-7 south runway and the TAC-2 east runway For comparison, samples from two other sites, Point Mugu (south) and the desert test site, were also analyzed. No propeller damage occurred during operations made at these two sites. The complete results of the petrographic analysis are presented in Appendix A for all four sites. These data show that all three sites in the vicinity of Edwards AFB had similar mineral compositions. It is apparent, therefore, that the mineral composition is not the variable that caused the propeller damage at the CV-7 and/or the TAC-2 sites since no damage was evident after operations at the desert test site. Since only minor differences exist in the grain-size distribution of the soil at the three Edwards AFB sites, it is also apparent that this is not the damaging variable. It can only be theorized that the type of operation (wing angle) is the pertinent variable with respect to the amount, size, and route of recirculated soil particles that caused the propeller damage.

15. Vertical takeoffs (90-deg wing angle) made at the desert test site resulted in no propeller damage, so it follows that the vertical takeoff at the TAC-2 site did not cause the severe propeller erosion. Thus, it appears that the eight takeoffs and eight landings with 25-deg wing angles at the CV-7 site caused the propeller damage. The wing-angle range for STOL operation of the XC-142A is 0-35 deg. It is believed that erosion by recirculated soil particles will occur on takeoffs between 25- and 35-deg wing angle, and that little or no damage will occur at wing angles between 0 and 20 deg and at 90 deg. This belief is based on the data presented herein and on visual observations of the aircraft

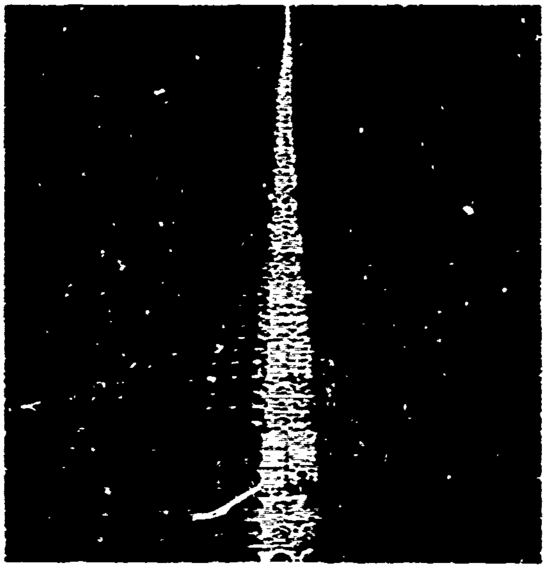
operations. Damage is not likely to occur on landings since the power is cut immediately after touchdown. The preciseness of the wing-angle ranges described above and the effect that a change in soil type may have on them are unknown, but these could very likely be determined by a reasonably simple study and proper manipulation of the variables.

## Conclusions

16. From a soils standpoint the overall performance of the XC-142A was good. The flotation characteristics of the nose gear should be increased, and means should be provided to prevent future derimming as occurred at Point Mugu. (Note: These modifications are being incorporated into the design of future aircraft.)

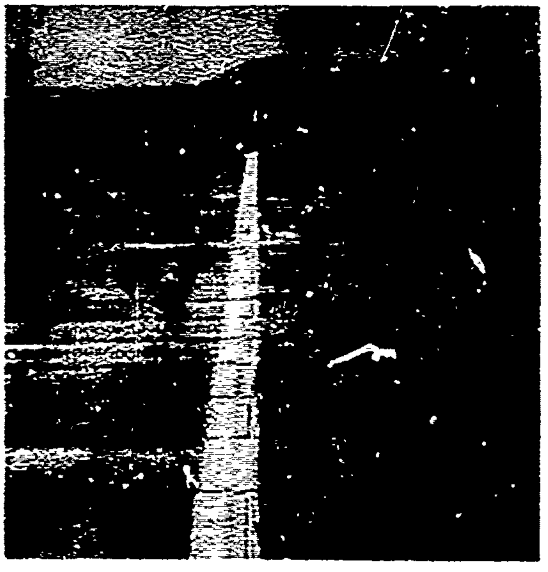
17. The results presented herein indicate that additional study of the relation of wing angle versus soil recirculation is needed. The availability of this information could minimize the potential damage from recirculated particles and help define proper pilot techniques and wing-angle settings for specific soil types.

18. With the exception of the test at Point Mugu where the nose gear dug into the soil when the tires derimmed, only moderate rutting was noted. Because the sites were generally very dry, the aircraft's ability to operate from a weak wet clay was not determined.

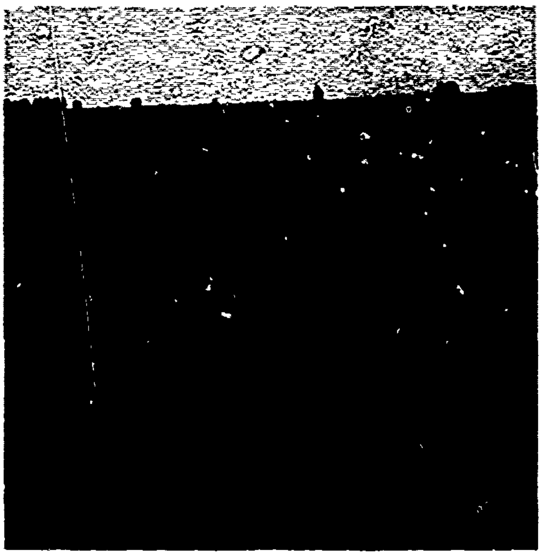


Photograph 1. Pierced-steel landing mat (M6),
Twenty-nine Palms, Calif. (MCAS)





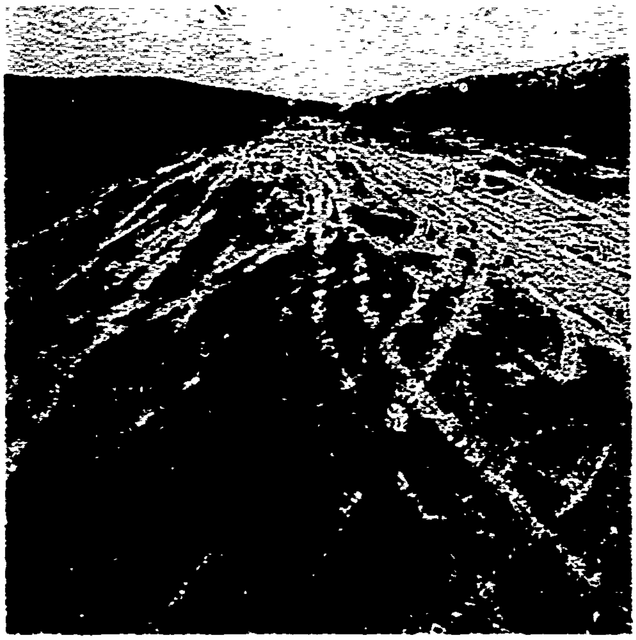
Photograph 2. M9M1 landing mat, Twenty-nine
Palms, Calif. (MCAS)



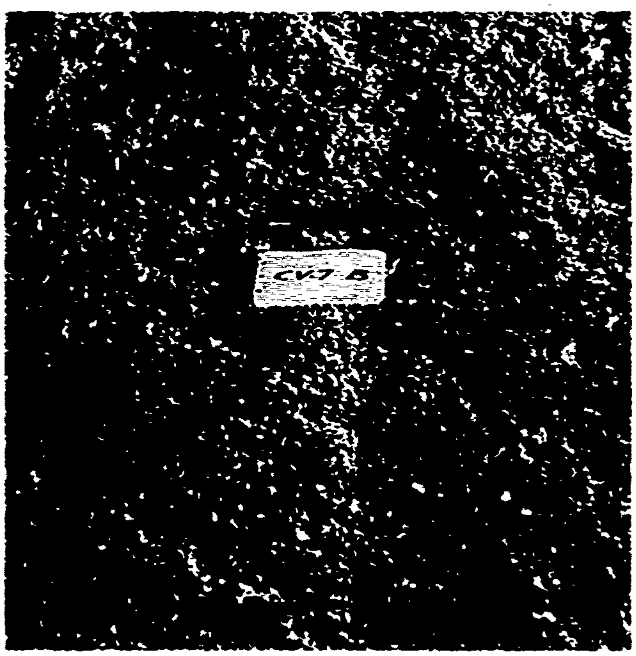
Photograph 3. Sod field (north site), Point Mugu, Calif. (NAS)



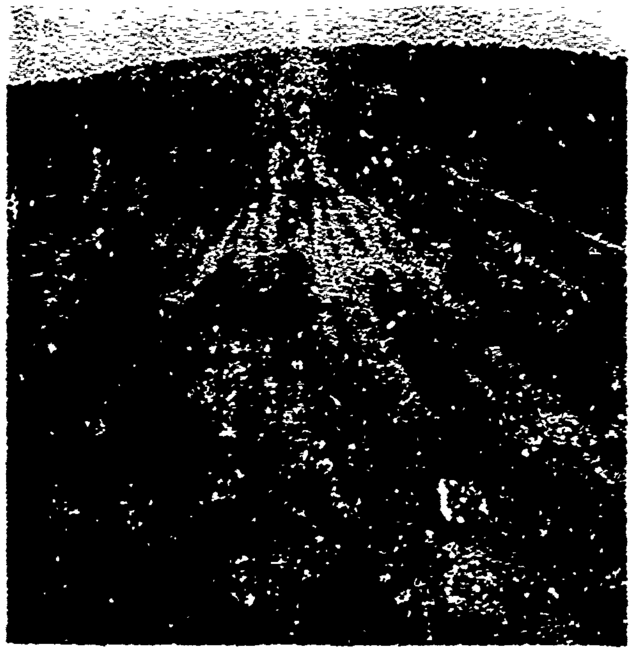
Photograph 4. Soil density determination being made with nuclear equipment



Photograph 5. General view of CV-7 (north) runway. This site was not used



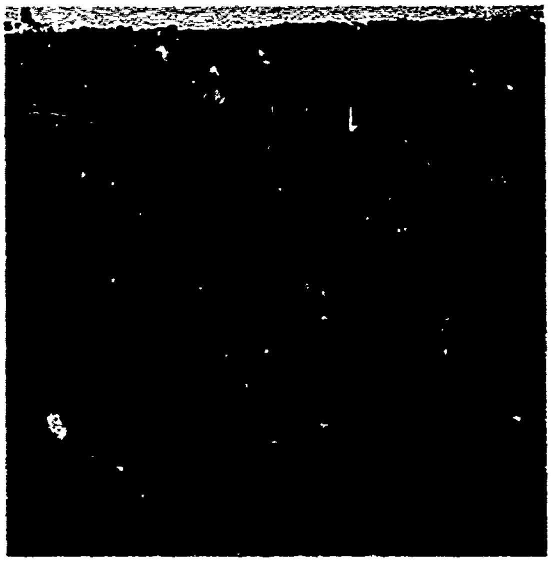

Photograph 6. Close-up of CV-7 (north) runway



Photograph 7. General view of TAC-2 (west) runway. This site was not used



Photograph 8. Close-up of TAC-2 (west) runway



Photograph 9. Sod field (south site), Point Mugu, Calif. (NAS)



Photograph 10. Buried nose gear, Point Mugu, Calif. (south site)

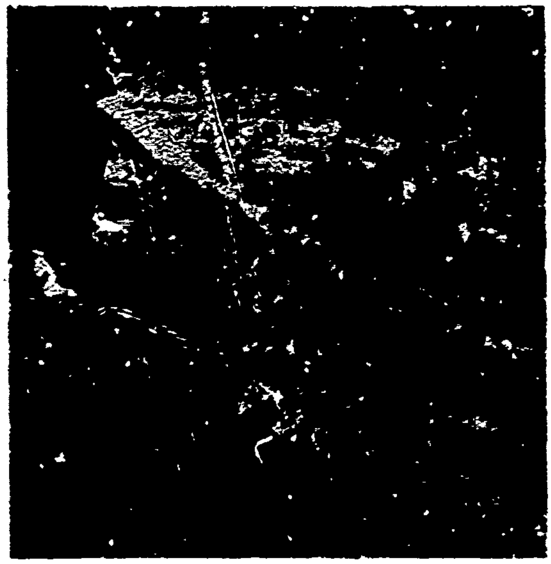
Photograph 11. Close-up of buried nose gear, Point Mugu, Calif. (south site)




Photograph 12. Vertical takeoff after nose gear buried, Point Mugu, Calif. (south site)

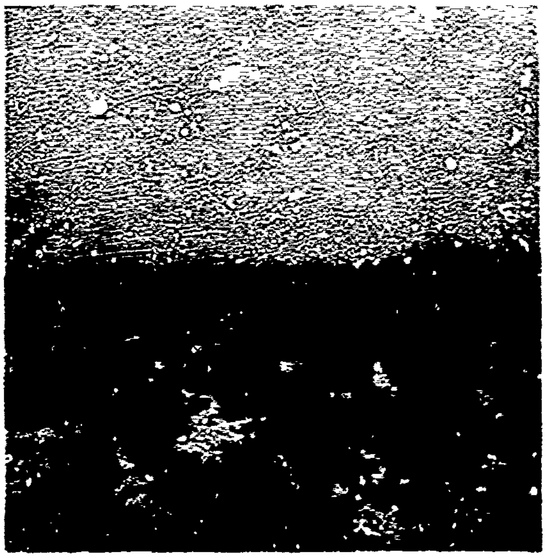
Photograph 13. Derimmed, flat tires on
XC-142A nose gear

Photograph 14. Average ruts at Point Mugu,
Calif. (south site)

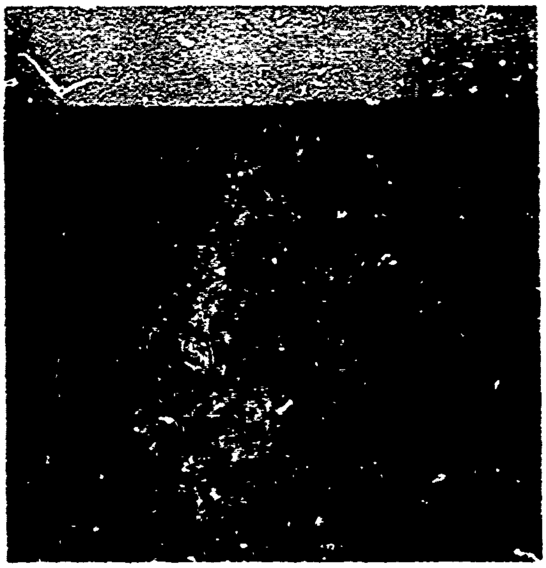


Photograph 15. Loose sod, Point Mugu, Calif. (south site)





Photograph 16. Desert test site near Edwards AFB before traffic



Photograph 17. Desert test site near
Edwards AFB after traffic



Photograph 18. XC-142A landing at desert test site
near Edwards AFB, Calif.

Photograph 19. Average ruts at desert test site, Edwards AFB, Calif.

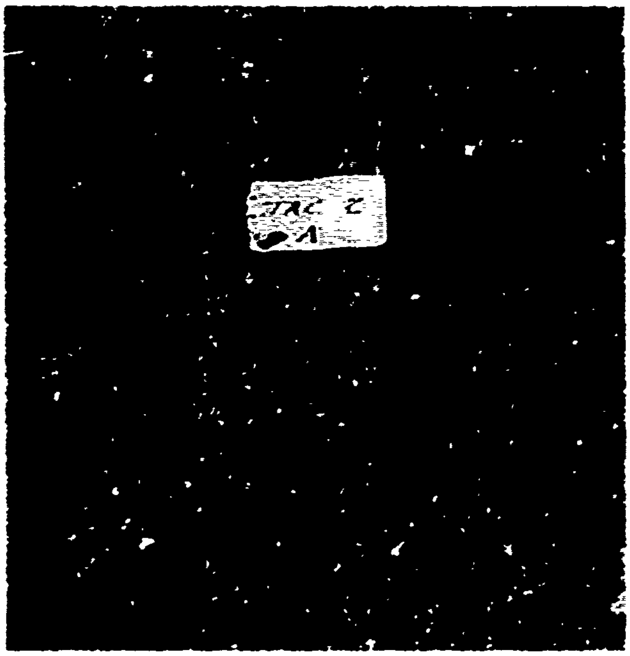


Photograph 20. General view of CV-7 (south) runway, Edwards AFB, Calif. This site was used for eight takeoffs and eight landings

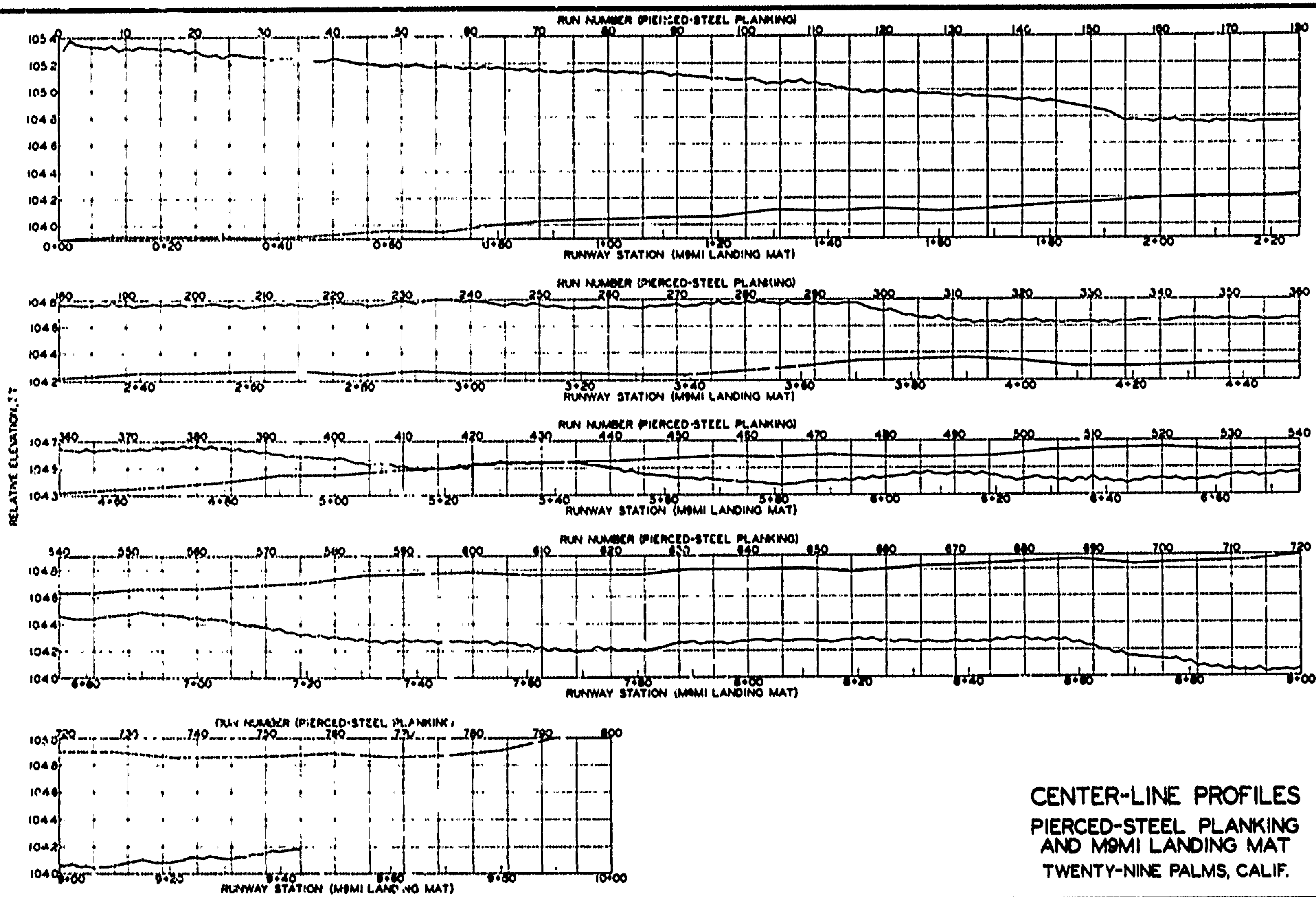
Photograph 21. Close-up of CV-7 (south) runway, Edwards AFB, Calif.



Photograph 22. General view of TAC-2 (east) runway, Edwards AFB, Calif. This site was used for one STOL landing and one vertical takeoff



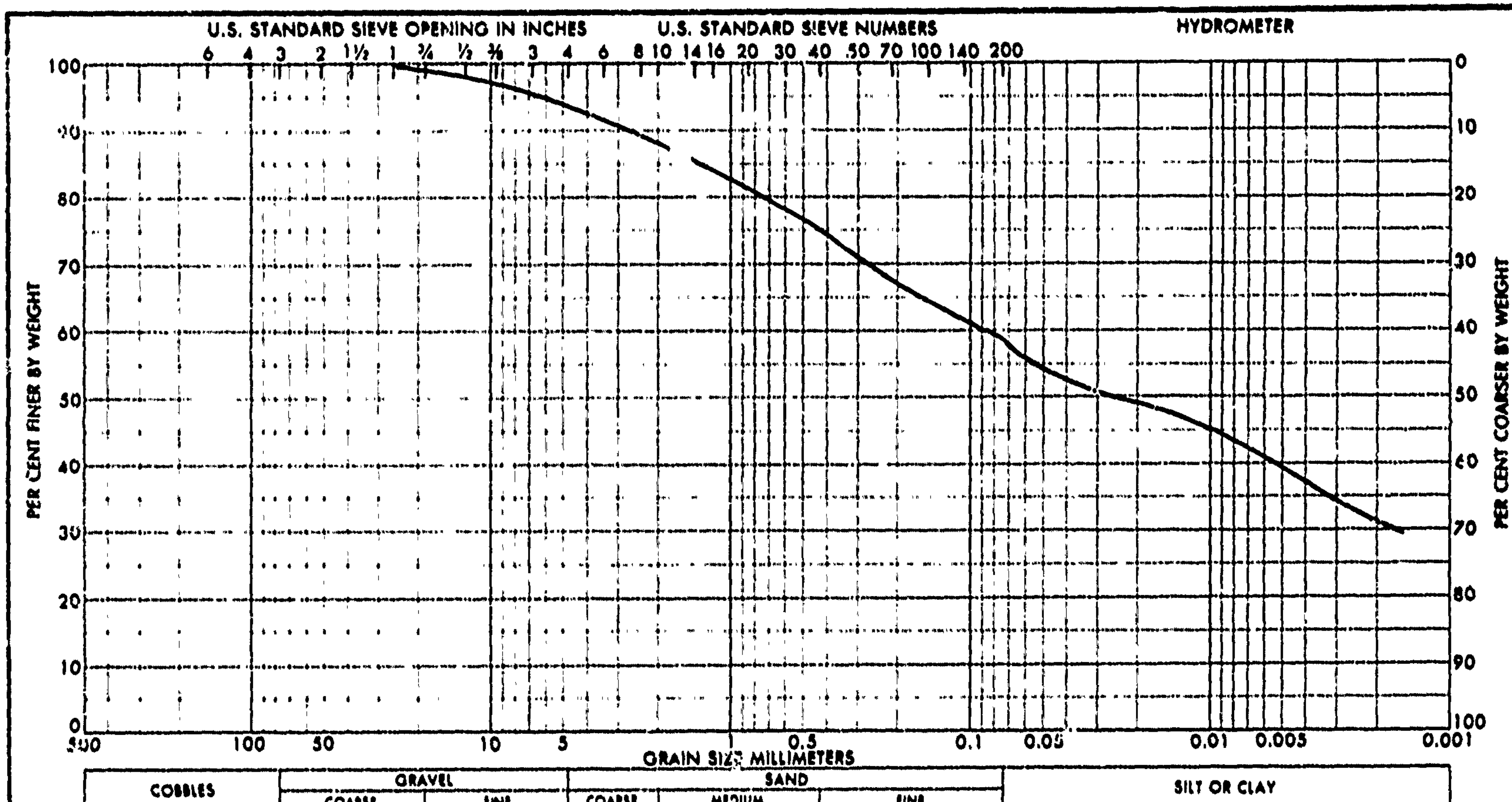

Photograph 23. Close-up of TAC-2 (east) runway,
Edwards AFB, Calif.




CENTER-LINE PROFILES
PIERCED-STEEL PLANKING AND M9MI LANDING MAT
TWENTY-NINE PALMS, CALIF.



PLATE 1




| SAMPLE NO | ELEV OR DEPTH | CLASSIFICATION | NAT W% | LL | PL | PI |
|---|---|---|---|---|---|---|
| 1 | 0-4 | Clay (CL), brown | | 37 | 16 | 21 |
| | | sp gr = 2.69 | | | | |

PROJECT XC-142A

AREA Twenty-nine Palms, Calif.

BORING NO. (MCAS)

DATE

GRADATION CURVES

PLATE 2

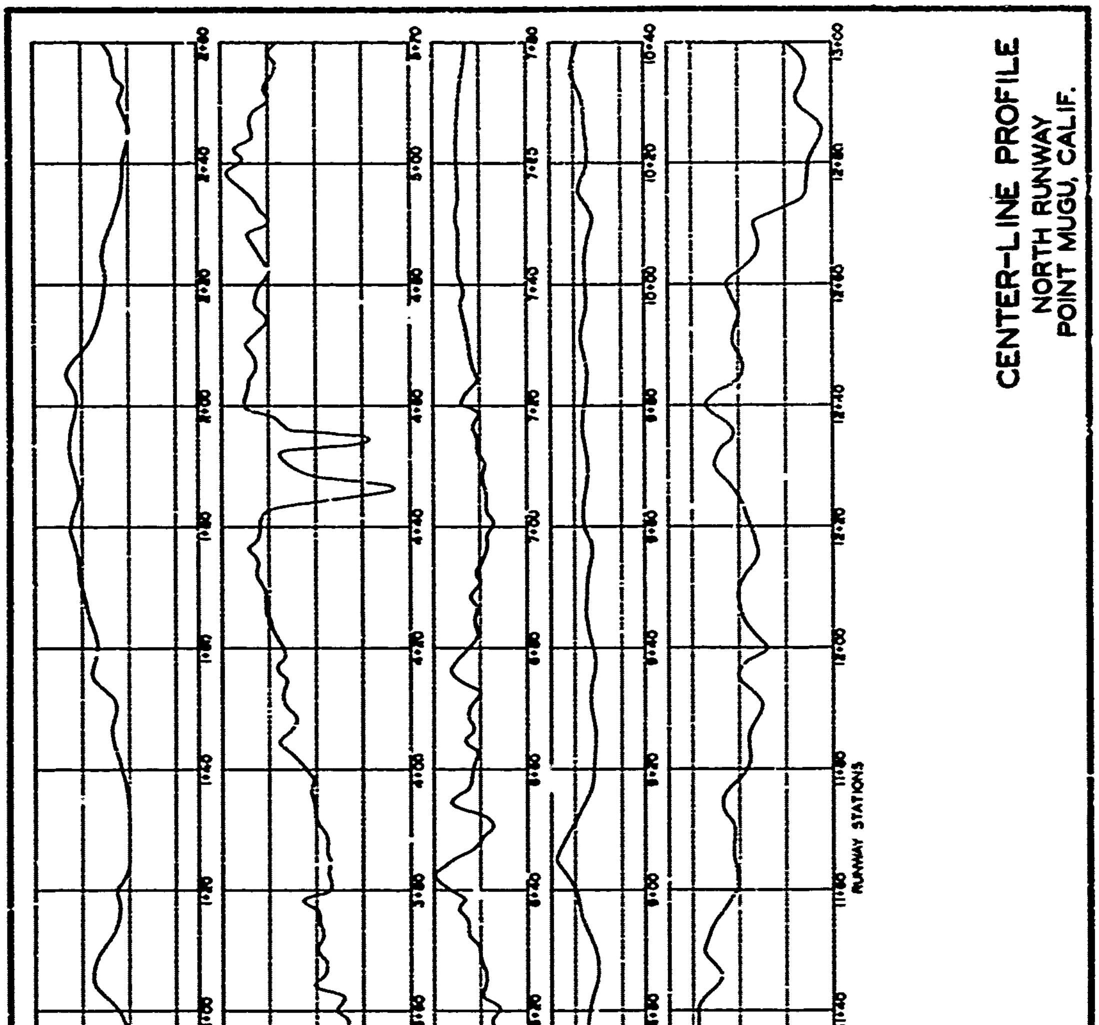

CENTER-LINE PROFILE
NORTH RUNWAY
POINT MUGU, CALIF.
RUNWAY STATIONS
RELATIVE ELEVATION FT



PLATE 3

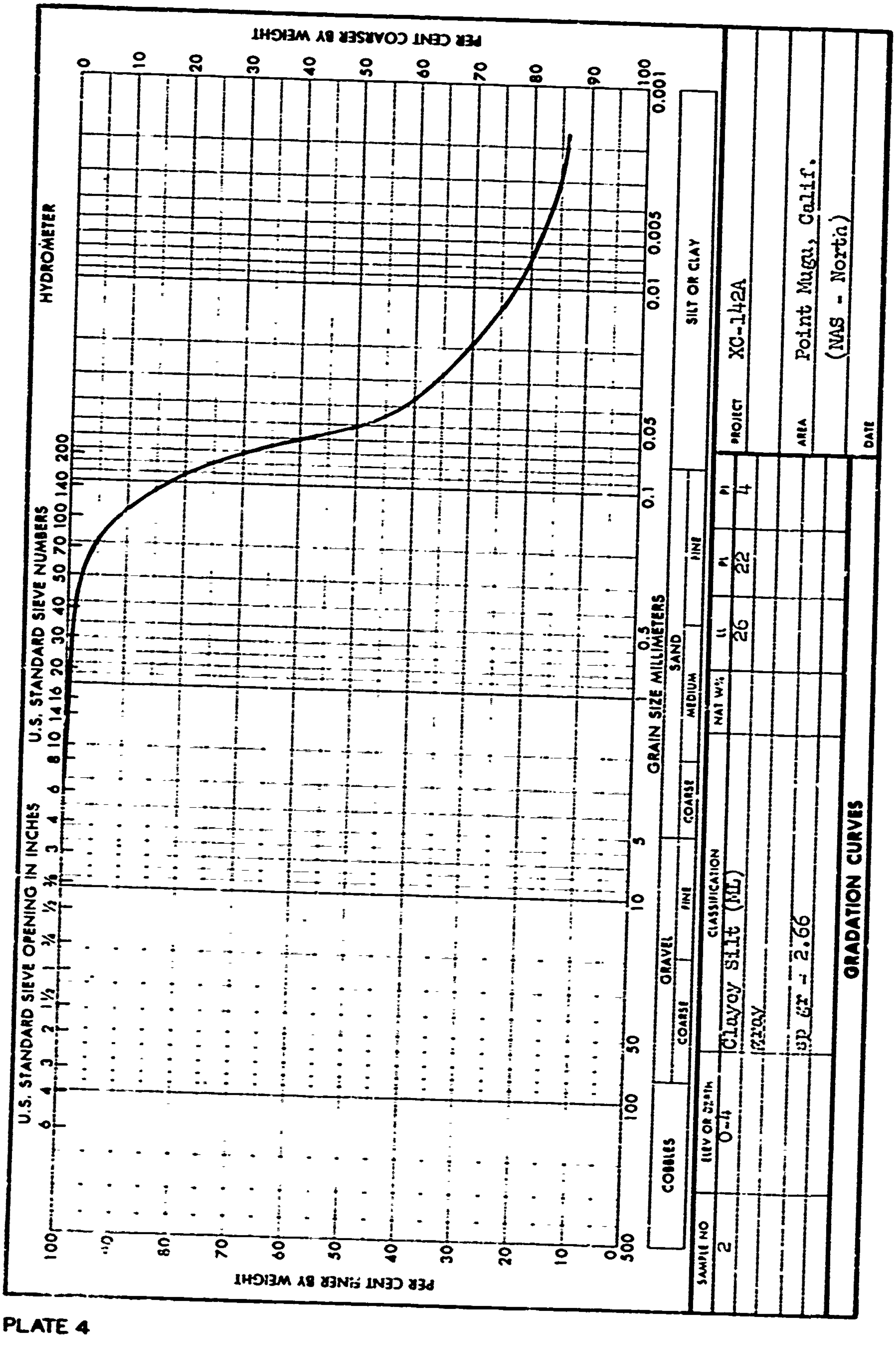
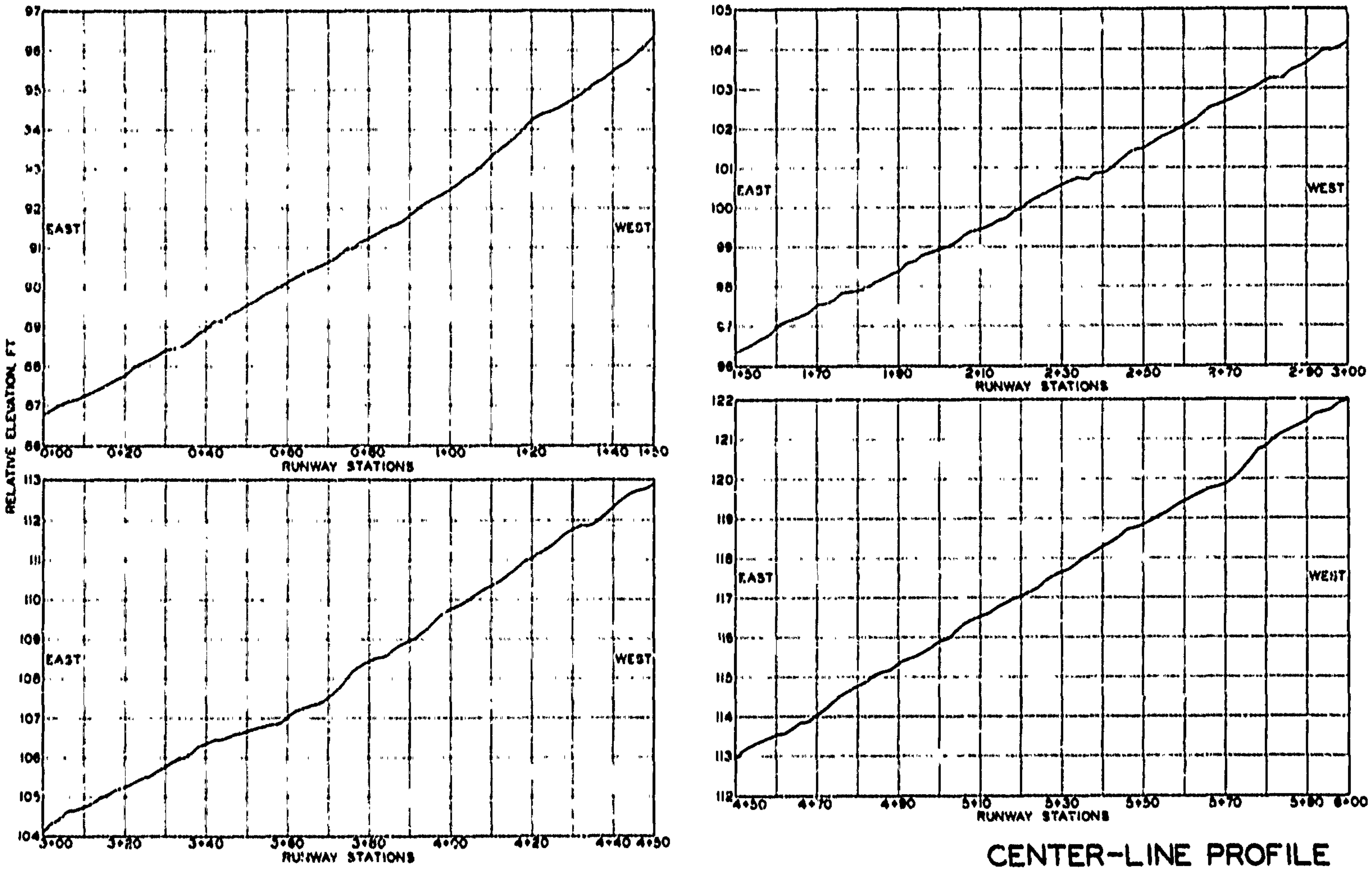

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PER CENT COARSER BY WEIGHT
PER CENT FINER BY WEIGHT
GRAIN SIZE MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
SAMPLE NO
ELEV OR DEPTH
CLASSIFICATION
NAT W%
LL
PL
PI
2
0-4
Clayey Silt (ML)
Gray
SP GR - 2.66
26
22
4
PROJECT
XC-142A
AREA
Point Mugu, Calif.
(NAS - North)
DATE
GRADATION CURVES

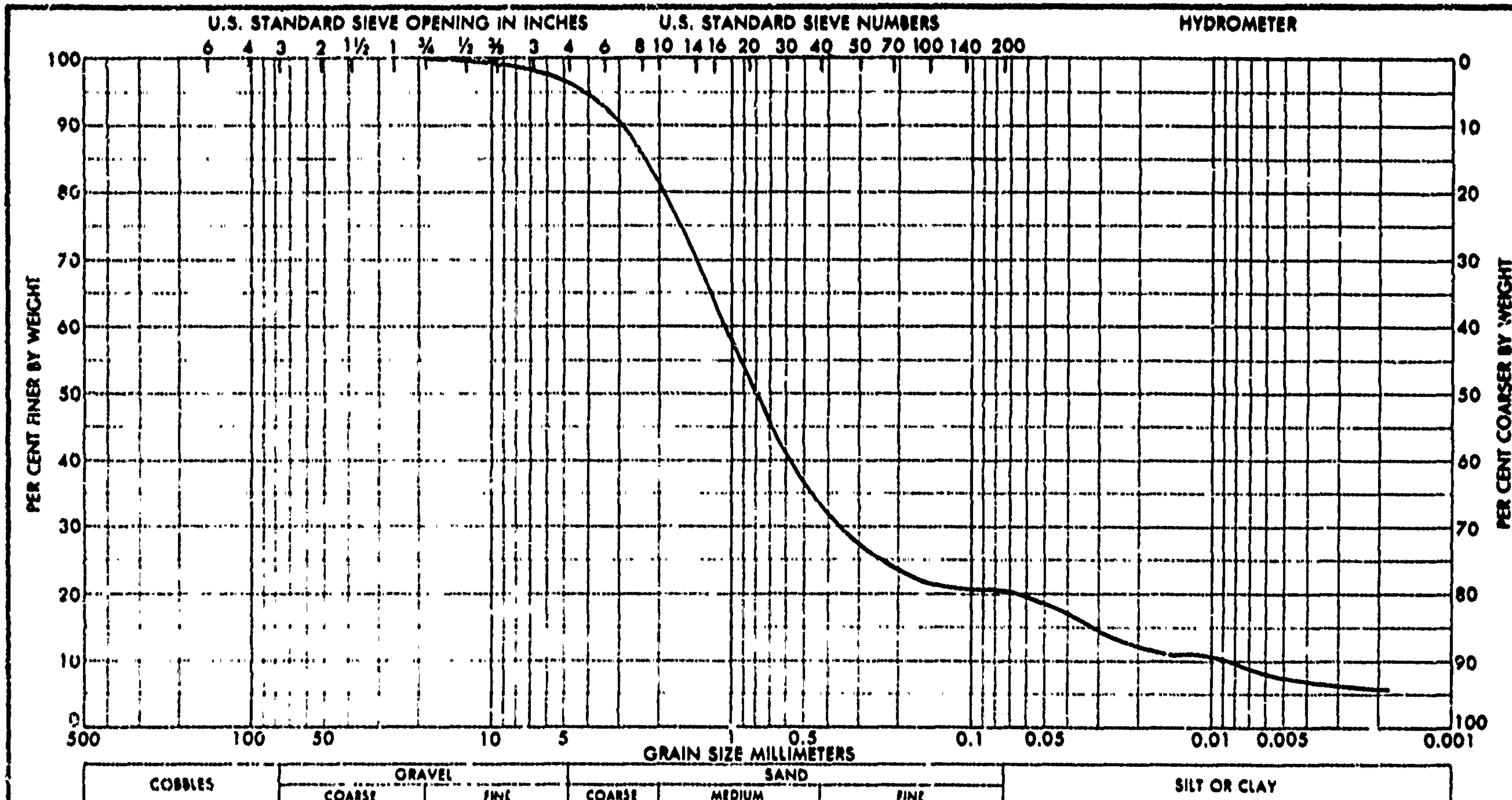
PLATE 4




CENTER-LINE PROFILE
CV-7 (NORTH) RUNWAY
EDWARDS AFB, CALIF.



PLATE 5

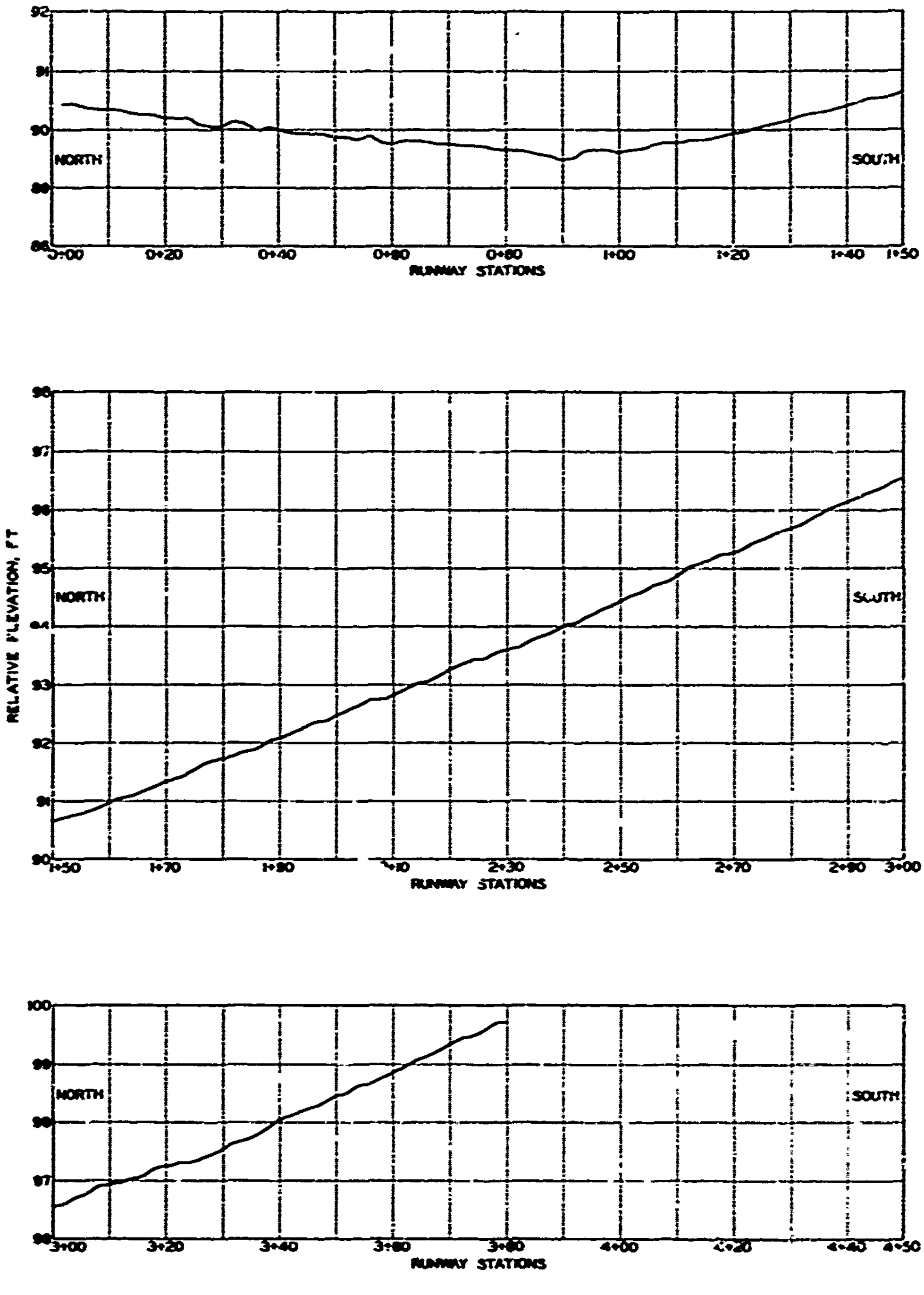



| SAMPLE NO | ELEV OR DEPTH | CLASSIFICATION | NAT W% | LL | PL | PI* |
|---|---|---|---|---|---|---|
| CV-7 | SURF | CLAYEY SAND (SC), TAN, GS=2.66 | | 24 | 16 | 8 |
| | | *ON -40 MATERIAL | | | | |

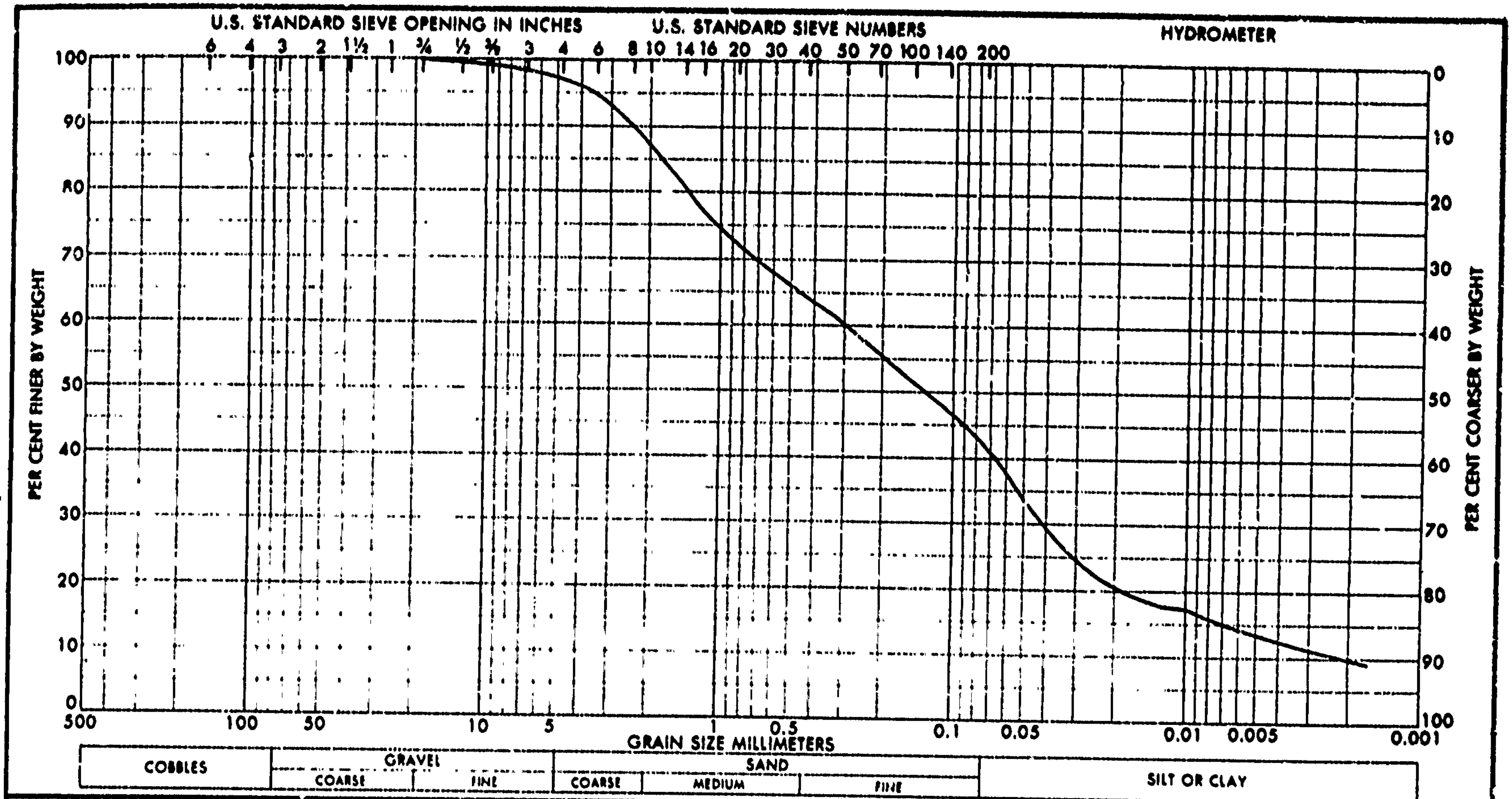
GRADATION CURVE

EDWARDS AFB, CALIF.
CV-7 (NORTH) RUNWAY

PLATE 6




CENTER-LINE PROFILE
TAC-2 (WEST) RUNWAY
EDWARDS AFB, CALIF.

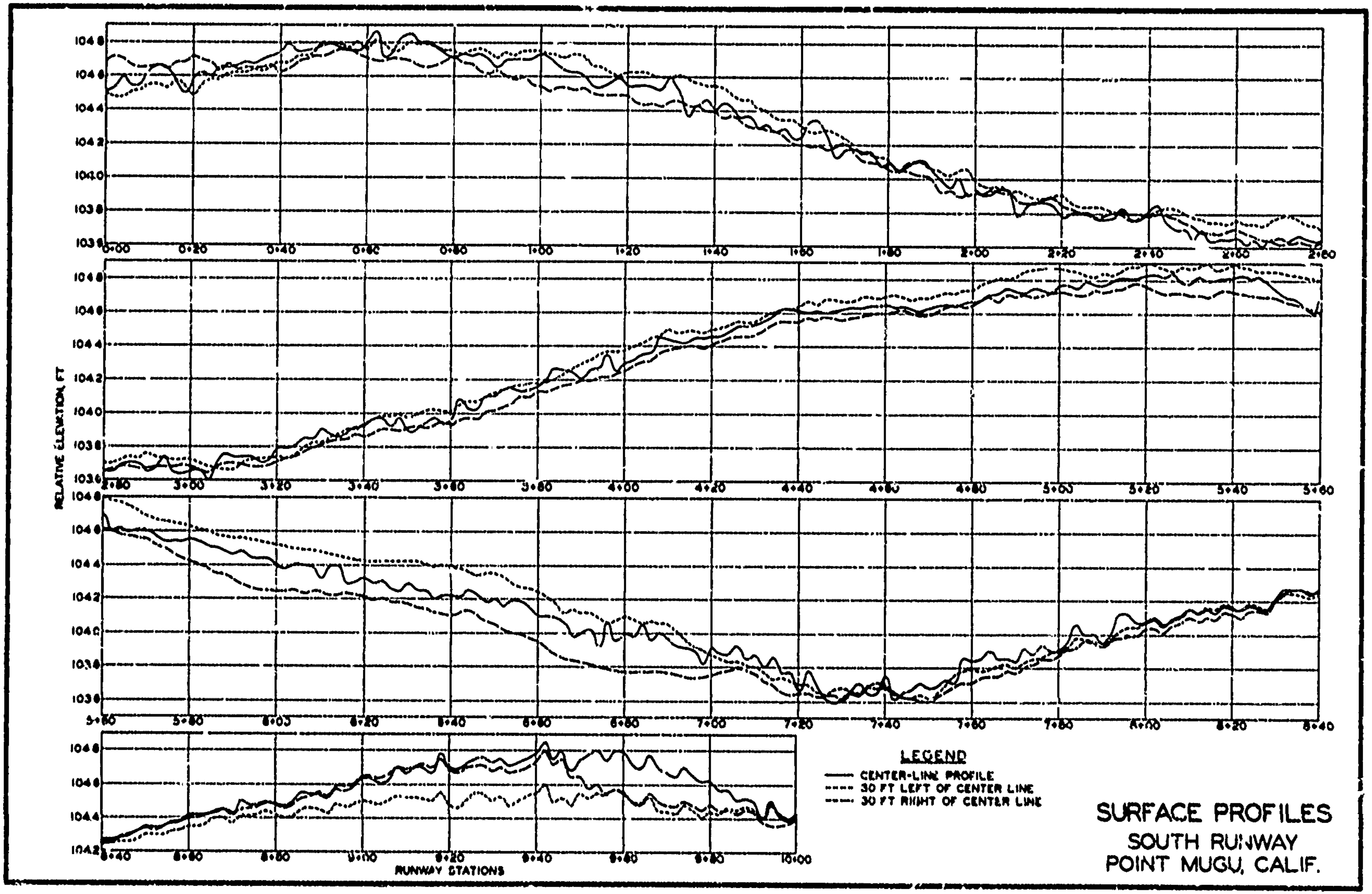



| SAMPLE NO | ELEV OR DEPTH | CLASSIFICATION | NAT W% | LL | PL | PI* |
|---|---|---|---|---|---|---|
| TAC-2 | SURF | CLAYEY SAND (SM-SC), TAN, GS = 2.67 | | 25 | 18 | 7 |
| | | *ON -40 MATERIAL | | | | |

**GRADATION CURVE**

EDWARDS AFB, CALIF.
TAC-2 (WEST) RUNWAY

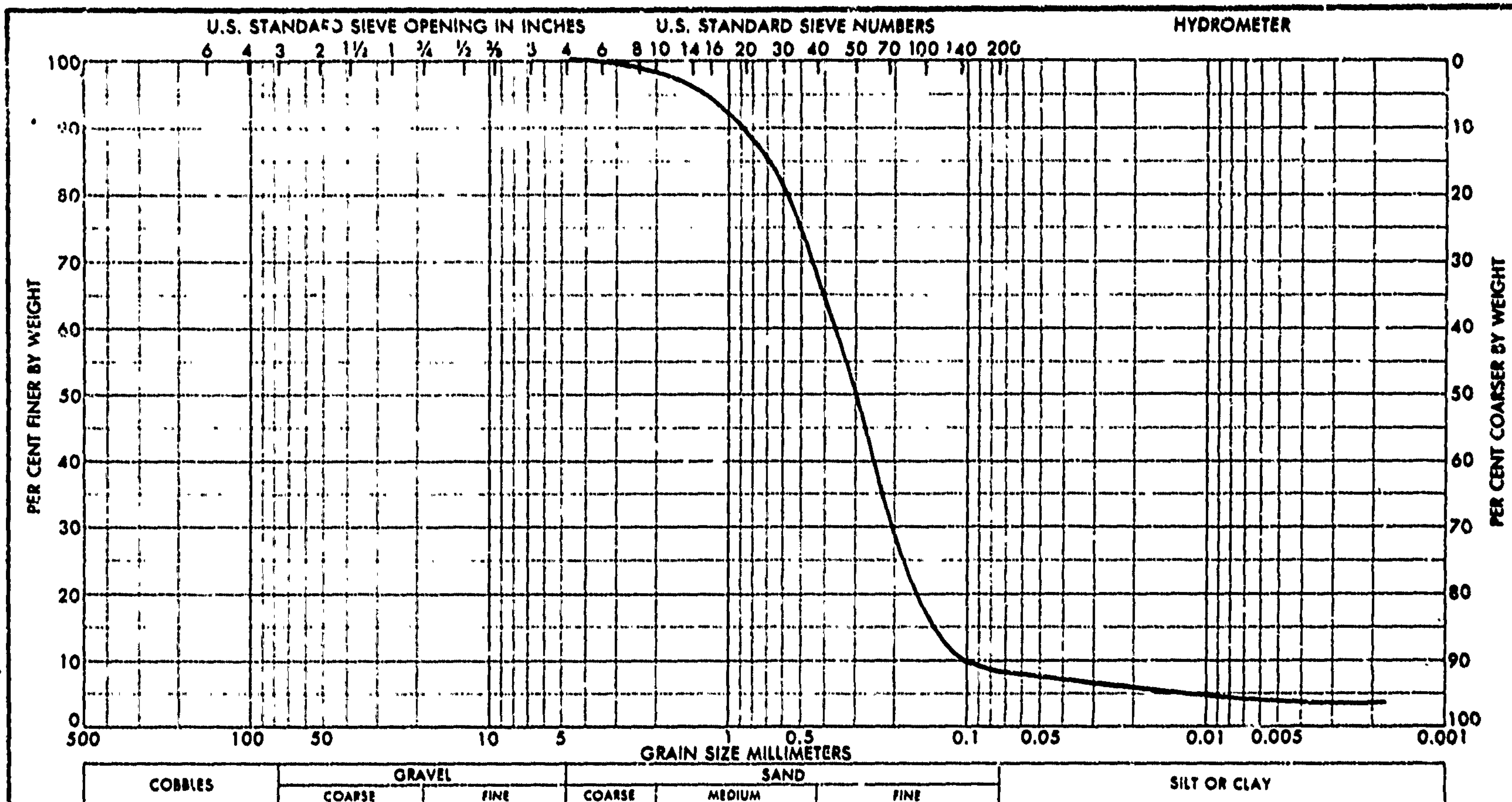
PLATE 8




SURFACE PROFILES
SOUTH RUNWAY
POINT MUGU, CALIF.



PLATE 9




| SAMPLE NO | ELEV OR DEPTH | CLASSIFICATION | NAT W% | LL | PL | PI |
|---|---|---|---|---|---|---|
| 3 | 0-4 | Silty Sand (SP-SM) | | | | N. P. |
| | | gray | | | | |
| | | sp gr = 2.64 | | | | |

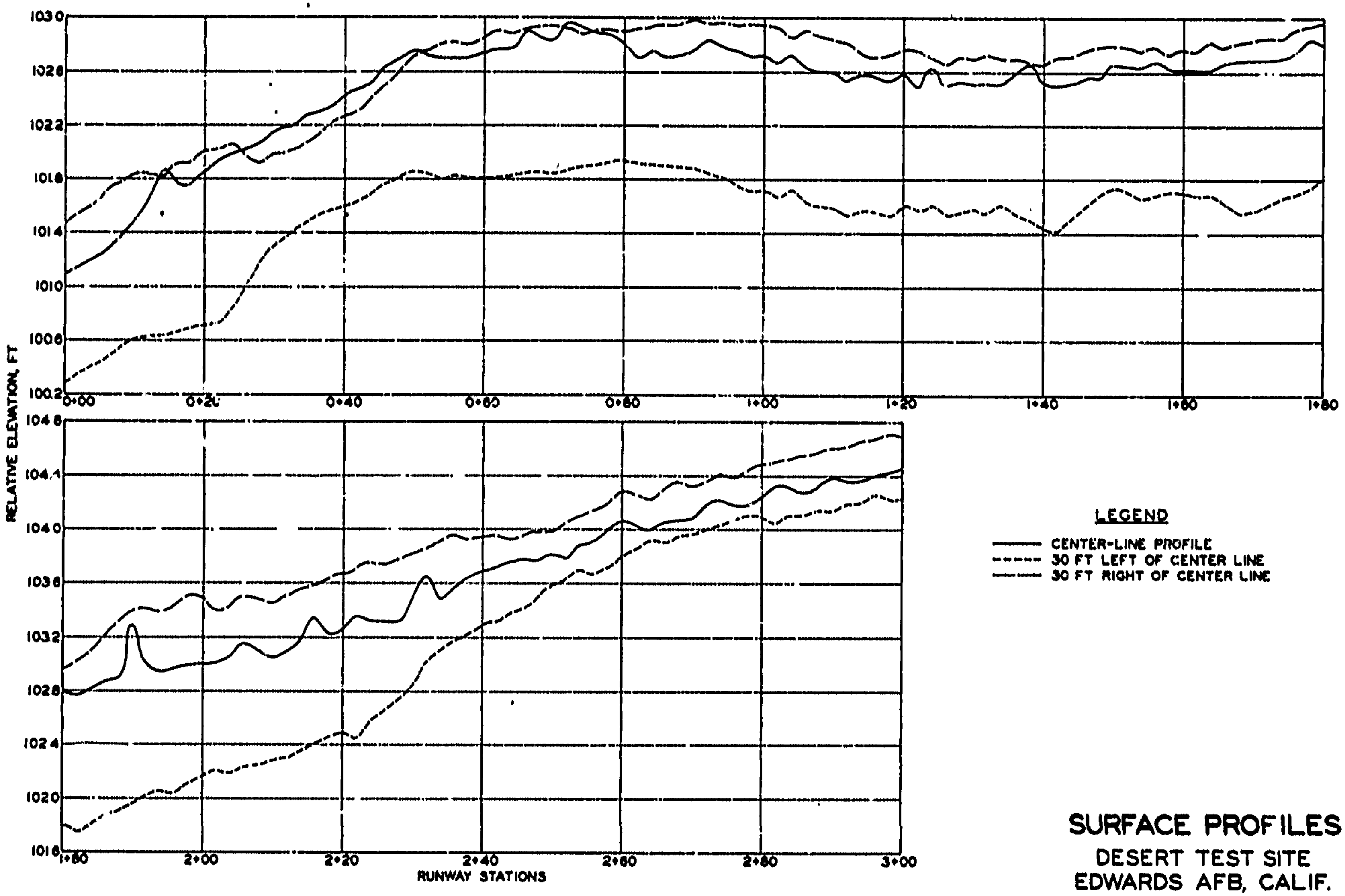
PROJECT XC-142A

AREA Point Mugu, Calif. (NAS - South)

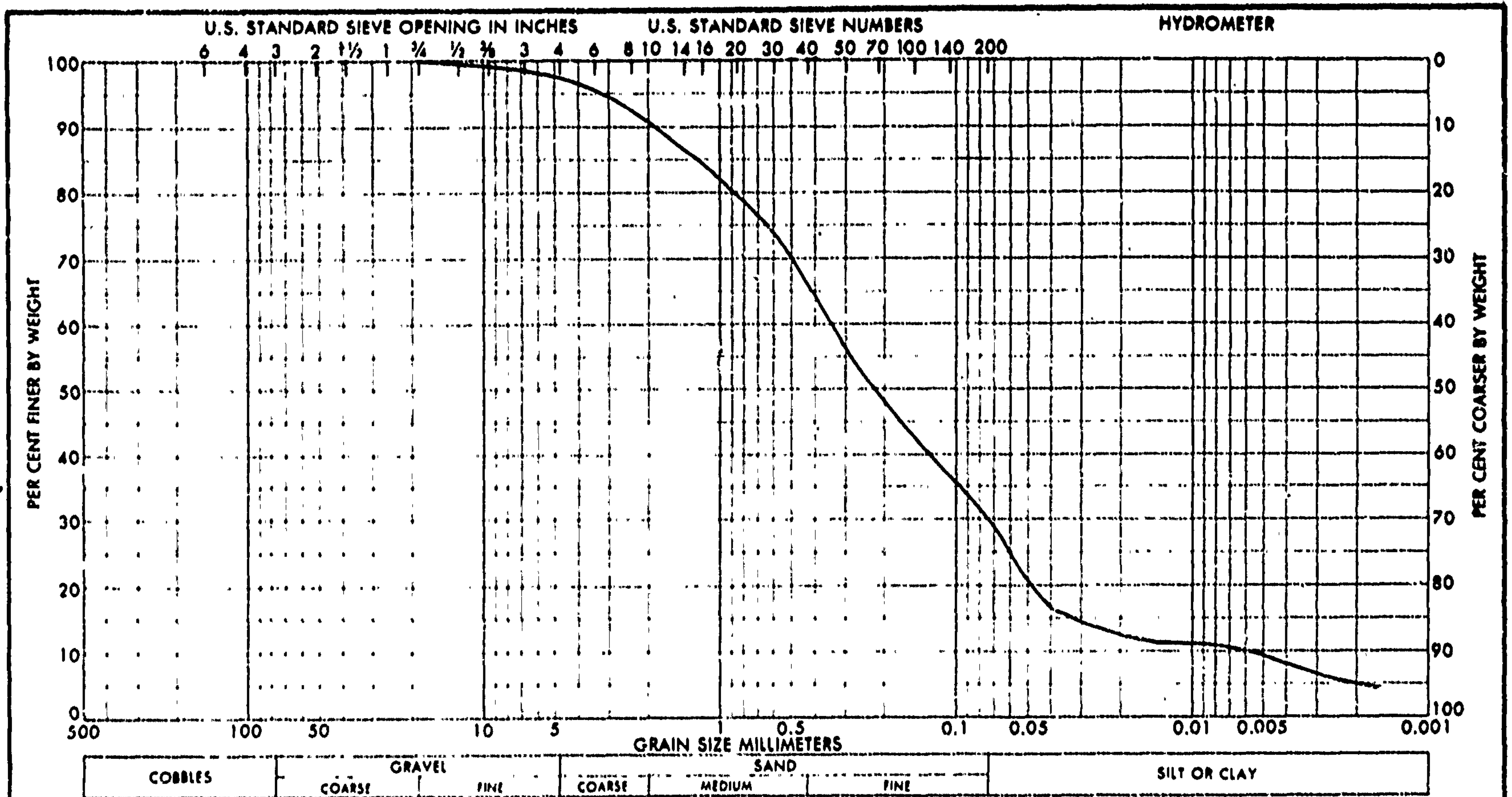
DATE

GRADATION CURVES

PLATE 10




**SURFACE PROFILES**
DESERT TEST SITE
EDWARDS AFB, CALIF.

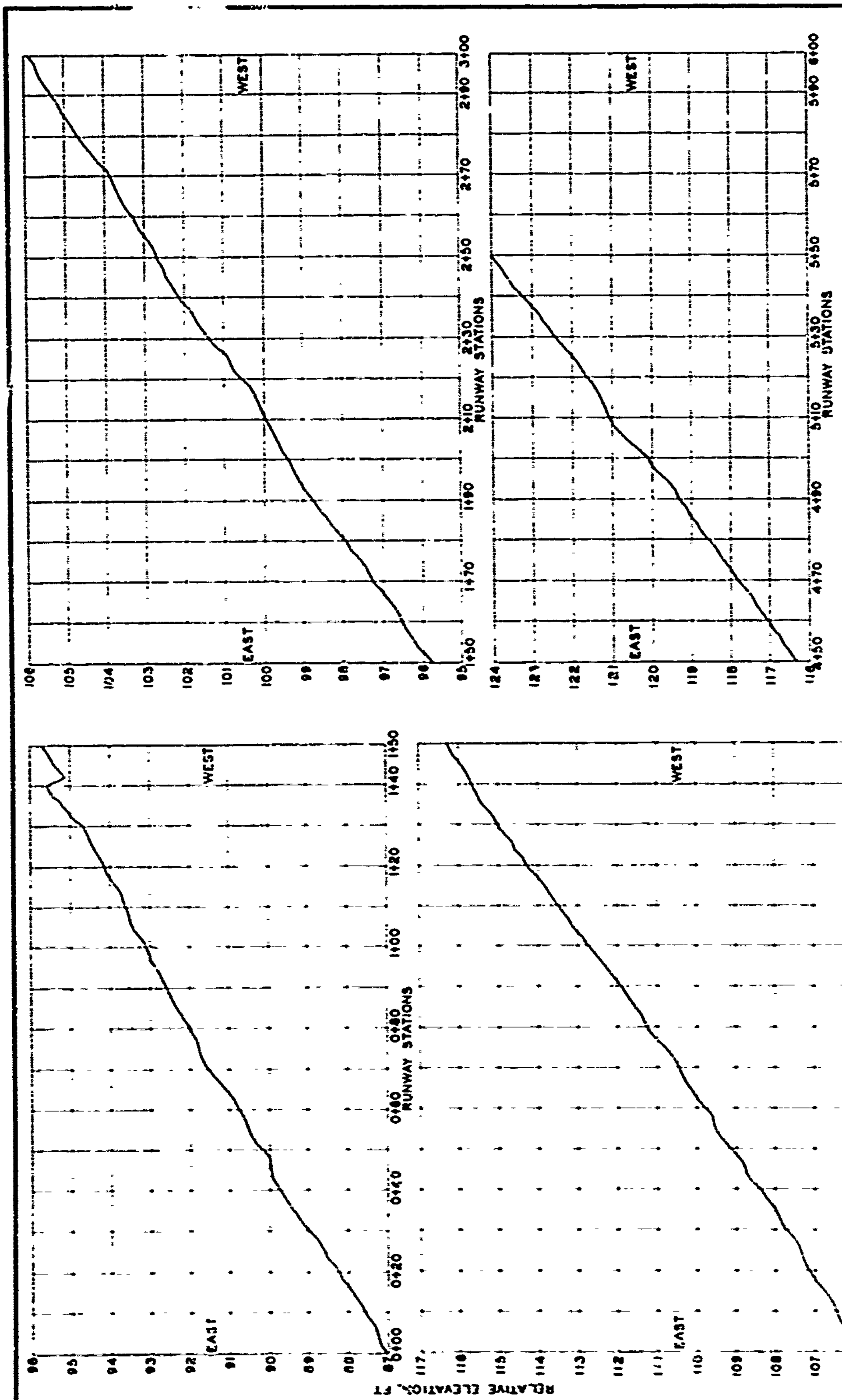



| SAMPLE NO | ELEV OR DEPTH | CLASSIFICATION | NAT W% | LL | PL | PI |
|---|---|---|---|---|---|---|
| 4 | 0-4 | SILTY SAND (SM), BROWN, GS = 2.66 | | 19 | 17 | 2 |

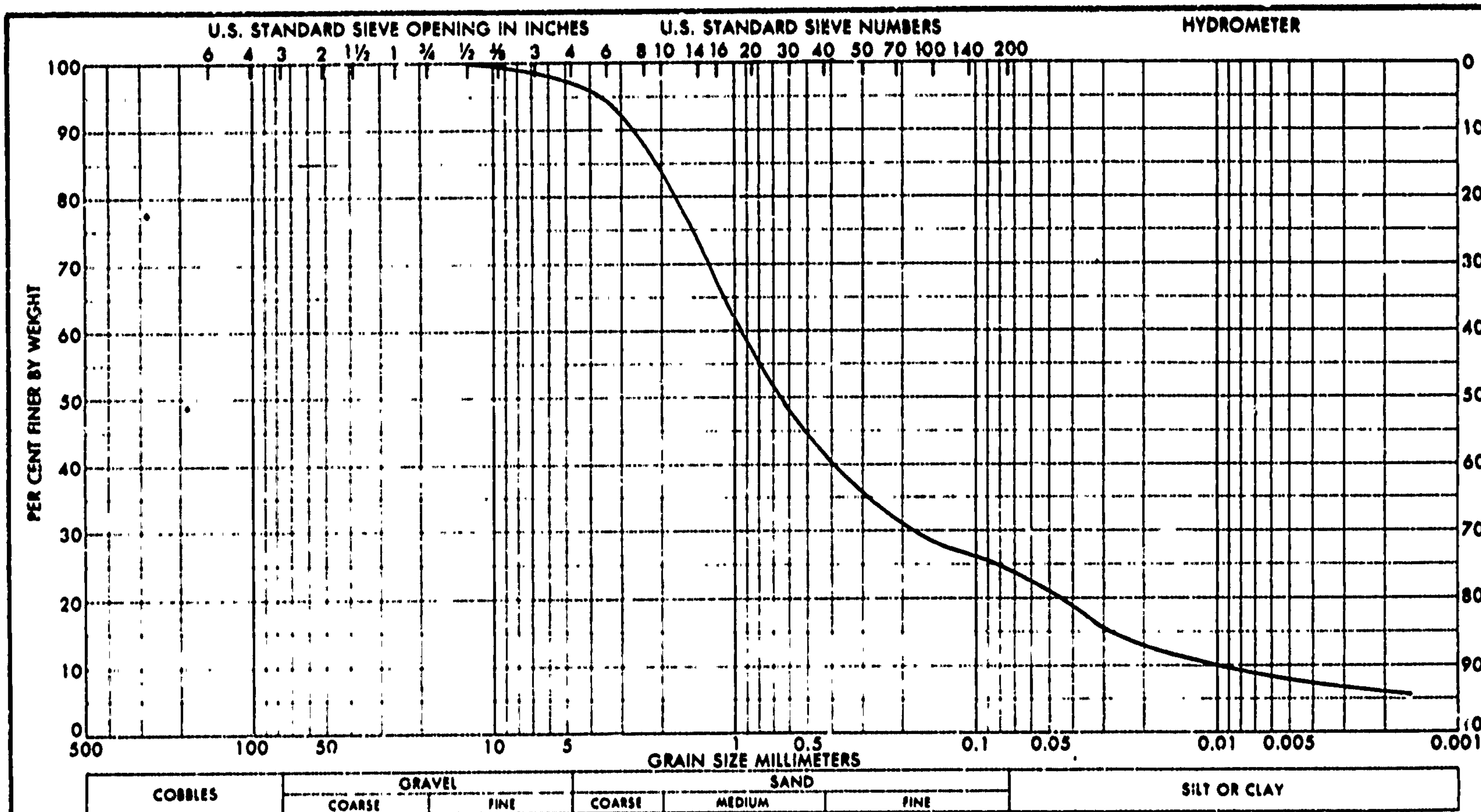
GRADATION CURVE

EDWARDS AFB, CALIF.
DESERT TEST SITE

PLATE 12




CENTER-LINE PROFILE
CV-7 (SOUTH) RUNWAY
EDWARDS AFB, CALIF.

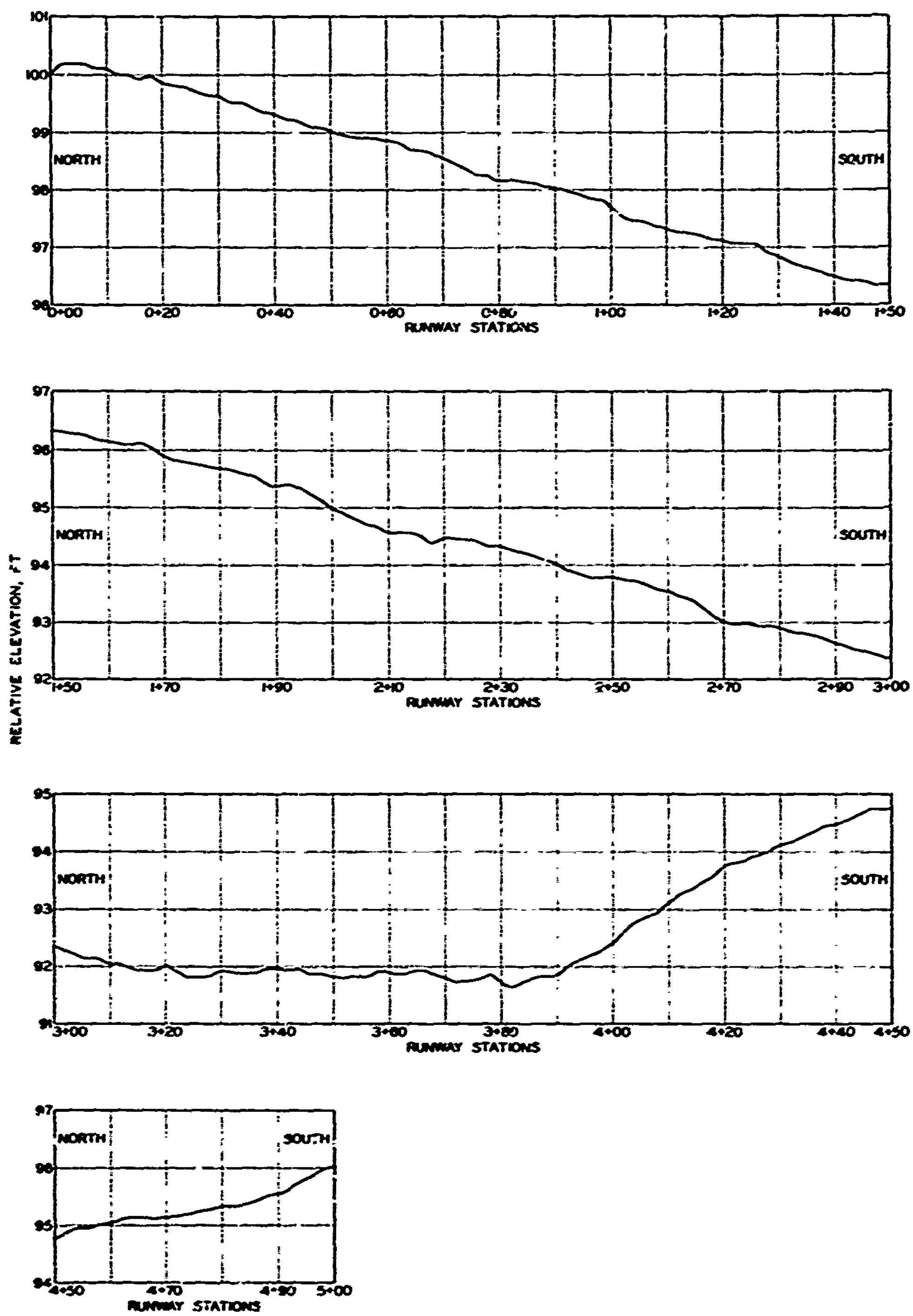



| SAMPLE NO | ELEV OR DEPTH | * CLASSIFICATION | NAT W% | LL | PL | PI* |
|---|---|---|---|---|---|---|
| CV-7 | SURF | SILTY SAND (SM), TAN, GS = 2.65 | | 23 | 20 | 3 |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | *ON -40 MATERIAL | | | | |
| | | | | | | |

GRADATION CURVE

EDWARDS AFB, CALIF.
CV-7 (SOUTH) RUNWAY

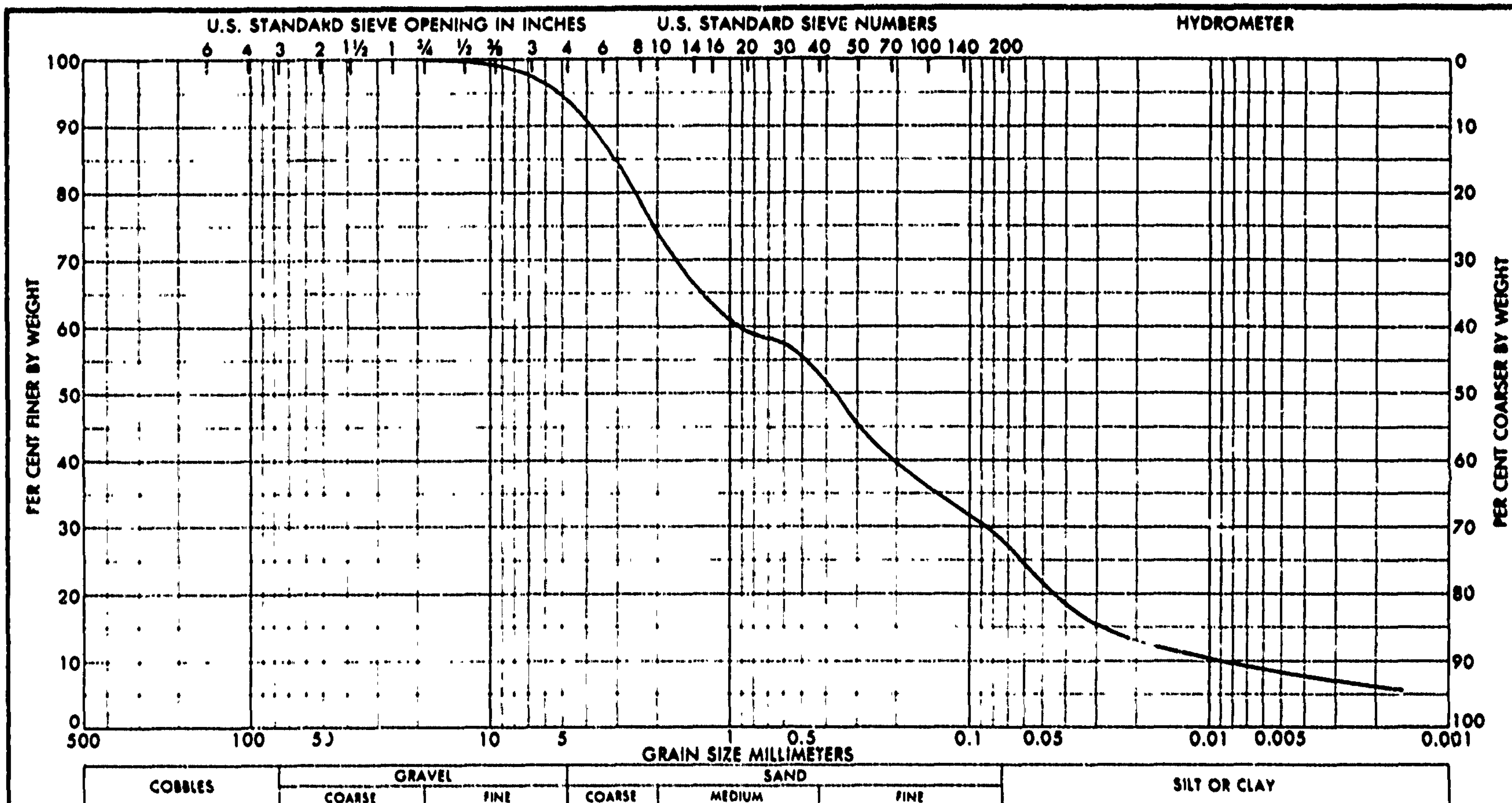
PLATE 14




# CENTER-LINE PROFILE

TAC-2 (EAST) RUNWAY

EDWARDS AFB, CALIF.




| SAMPLE NO | ELEV OR DEPTH | CLASSIFICATION | NAT W% | LL | PL | PI* |
|---|---|---|---|---|---|---|
| TAC-2 | SURF | SILTY SAND (SM), TAN, GS = 2.66 | | 19 | 17 | 2 |
| | | *ON -40 MATERIAL | | | | |

## GRADATION CURVE

EDWARDS AFB, CALIF.
TAC-2 (EAST) RUNWAY

PLATE 15

## APPENDIX A: MINERALOGICAL ANALYSIS OF SOILS

### Background

1. Tests are being made at WES to determine particle-size distribution and Atterberg limits of soils from unpaved landing areas to develop data that will show why some landing areas are associated with more erosion of V/STOL aircraft parts than others. This petrographic report describes the mineralogy of the soil from four areas.

### Samples

2. Soil samples from surfaces of landing and takeoff sections of four runways were analyzed. The origins and other information concerning the samples are shown below:

| Location | Sample Size, g |
|---|---|
| Point Mugu, south site, Calif. | 274 |
| Desert test site, Edwards AFB, Calif. | 437 |
| TAC-2 (east) runway, Edwards AFB, Calif. | 3500 |
| CV-7 (south) runway, Edwards AFB, Calif. | 3500 |

### Test Procedure

3. Each sample was dry sieved over a nest of sieves consisting of the Nos. 4, 8, 16, 30, 50, 100, and 200 sieves, and cumulative grading curves were prepared from the sieve analyses. The individual sieve sizes of each sample were examined and compared with one another under a stereomicroscope or a petrographic microscope as appropriate. Selected sizes of the samples from Point Mugu and the Edwards AFB desert test site were analyzed by X-ray diffraction. X-ray diffraction patterns of all samples taken from the as-received material, ground to pass No. 325 sieve, were made and compared. The material passing No. 200 in each sample was wet sieved over No. 400 sieve and examined by X-ray diffraction. Microscope counts and X-ray diffraction results were used to supplement each other.

## Results

Point Mugu south site

4. The sample was a light brownish-gray beach sand composed of rounded to subangular sand grains. The coarser sizes were made up of a mixture of fine-grained igneous rocks, graywacke, sandstone, chert, quartz, feldspar, and broken shell fragments, along with considerable dried vegetation, such as weed stems, etc. Translucent to clear and white, clean, dense quartz and feldspar grains increased rapidly in abundance as grain size diminished. Minor amounts of mica, amphibole, magnetite, and unidentified heavy mineral grains were present in the sizes passing the No. 50 sieve (297μ). Very minor amounts of clay, mostly montmorillonite, were present in the material passing the No. 200 sieve. The sieve analysis of the sample is shown in table A1. The shape of the cumulative gradation curve, shown in plate A1, is typical of fine- to medium-grained, fairly well-sorted beach sand.

Samples from Edwards AFB test sites

5. Sieve analyses of the samples appear in table A1, and cumulative grading curves for all three, based on dry sieving, are shown in plate A1. Soils from all three sites were very similar in composition and particle shape and were poorly sorted as compared with the Point Mugu soil sample. Table A2 presents the composition by sieve fractions of the sample from the desert test site. The composition of the samples from CV-7 (south) runway and TAC-2 (east) runway differed from that shown in table A2 only in having more quartz in the sizes passing the No. 200 sieve. All three samples appeared to be products of the decomposition of a granitic rock; the particle shapes are angular with reentrant angles. The sizes retained on the No. 50 sieve were composed largely of discrete mineral particles, predominantly quartz and feldspar, derived from breakdowns of the particles like those in the coarser sizes. In addition, minor amounts of weathered mica flakes, amphibole, magnetice and heavy mineral grains were present. Practically all the grains had a light coating of fine silt and clay. X-ray diffraction indicated that the clay was predominantly montmorillonite and was concentrated in the material

passing the No. 200 sieve. The extreme angularity of the particles indicated that the source of the soils was nearby, since little or no rounding of corners and edges was observed.

6. Sieve analyses of the samples (table A1) indicated that the sample from the desert test site was somewhat finer than the other two, but all three were medium-grained sands.

## Conclusions

7. Examination of all four samples revealed that the three from Edwards AFB were very much alike (plate A1). The Point Mugu sample was rounded to subangular beach sand derived from a mixed igneous, sedimentary, and metamorphic terrain (tables A1 and A3). The three samples from Edwards AFB were sands of angular and irregular particle shape derived from the breakdown of granite and consisting of about 50 percent quartz, 30 percent feldspar, and over 10 percent of granite fragments.

8. All three samples contained roughly similar amounts of quartz and feldspar. Quartz sands are used for sandblasting metal, removing paint, rust, and corrosion products. The angularity of the sand grains in the samples from Edwards AFB may have the effect of making them more abrasive than those from Point Mugu. T. D. Murphy* states that in sands used for sandblasting "angularity promotes faster cutting, but this is offset by a higher loss in fines. The peening action of a rounded grain is a desirable feature in achieving a satin finish for certain light metal castings, but a subangular grain is unsurpassed for fast cutting action."

9. No information on the size of material flying through the air when the aircraft is landing or taking off was furnished. It is believed, however, that under certain conditions, the material stirred up by propeller blast could simulate sandblasting. Probably this would occur when vertical or high-angle takeoffs and landings are made rather than when more conventional takeoffs are made.

* T. D. Murphy, Industrial Rocks and Minerals, The American Institute of Mining, Metallurgical, and Petroleum Engineers, 3d ed, New York, 1960, p 763.

Table A1

Sieve Analyses of Soils from Unpaved Runways

| Sieve Size | Individual Percent Retained | Cumulative Percent Retained | Cumulative Percent Passing |
|---|---|---|---|
| **Desert Test Site, Edwards AFB** | | | |
| 3/8-in. | 0 | 0 | 100 |
| No. 4 | 3 | 3 | 97 |
| No. 8 | 6 | 9 | 91 |
| No. 16 | 9 | 18 | 82 |
| No. 30 | 11 | 29 | 71 |
| No. 50 | 19 | 48 | 52 |
| No. 100 | 18 | 66 | 34 |
| No. 200 | 17 | 83 | 17 |
| Passing 200 | 17 | 100 | 0 |
| Total | 100 | | |
| **Point Mugu South Site** | | | |
| 3/8-in. | 0 | 0 | 100 |
| No. 4 | 2 | 2 | 98 |
| No. 8 | 1 | 3 | 97 |
| No. 16 | 4 | 7 | 93 |
| No. 30 | 12 | 19 | 81 |
| No. 50 | 31 | 50 | 50 |
| No. 100 | 37 | 87 | 13 |
| No. 200 | 10 | 97 | 3 |
| Passing 200 | 3 | 100 | 0 |
| Total | 100 | | |

| Sieve Size | Individual Percent Retained | Cumulative Percent Retained | Cumulative Percent Passing |
|---|---|---|---|
| **TAC-2 (East) Runway, Edwards AFB** | | | |
| 3/8-in. | 0 | 0 | 100 |
| No. 4 | 7 | 7 | 92 |
| No. 8 | 19 | 26 | 74 |
| No. 16 | 19 | 45 | 55 |
| No. 30 | 9 | 54 | 46 |
| No. 50 | 9 | 63 | 37 |
| No. 100 | 10 | 73 | 27 |
| No. 200 | 10 | 83 | 17 |
| Passing 200 | 17 | 100 | 0 |
| Total | 100 | | |
| **CV-7 (South) Runway, Edwards AFB** | | | |
| 3/8-in. | 0 | 0 | 100 |
| No. 4 | 5 | 5 | 95 |
| No. 8 | 12 | 17 | 83 |
| No. 16 | 26 | 43 | 57 |
| No. 30 | 18 | 61 | 39 |
| No. 50 | 12 | 73 | 27 |
| No. 100 | 8 | 81 | 19 |
| No. 200 | 6 | 87 | 13 |
| Passing 200 | 13 | 100 | 0 |
| Total | 100 | | |

Table A2

Composition of Soil Sample from Desert Test Site, Edwards AFB

| Constituent | Percent Composition of Soil Retained on Indicated Sieves* No. 16 | No. 30 | No. 50 | No. 100 | No. 200 | Passing No. 200** | Percent Composition of Whole Sample† |
|---|---|---|---|---|---|---|---|
| Igneous rock particles | 100 | 76 | 25 | 8 | 5 | 1 | 34 |
| Quartz | -- | 9 | 39 | 42 | 50 | 51 | 33 |
| Feldspar | -- | 14 | 26 | 30 | 23 | 27 | 20 |
| Mica | -- | 1 | 9 | 18 | 20 | 10 | 10 |
| Miscellaneous rocks and minerals†† | -- | -- | 1 | 1 | 2 | 10 | 2 |
| Weathered particles | -- | -- | -- | 1 | Tr | 1 | 1 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

* Percentage is based on count of more than 300 particles in each sieve fraction.

** Analysis was made on particles passing No. 200 and retained on No. 400 sieve.

† Percentage is based on gradation of samples as received and on the distribution of constituents by sieve fractions shown at left above.

†† SS-1 contains minor amounts of a 14-A clay, mica, and kaolin group clay, and amphibole. SS-3 contains the same minerals but more mica than SS-1. SS-4 contains more mica and amphibole and traces of 14-A and kaolin clays.

Table A3

Composition of Soil Sample, Point Mugu South Site

| Constituent | Percent Composition of Soil Retained on Indicated Sieves* No. 16** | No. 30 | No. 50 | No. 100 | No. 200 | Passing No. 200† | Percent Composition of Whole Sample†† |
|---|---|---|---|---|---|---|---|
| Igneous rocks | 47 | 46 | 11 | 1 | -- | -- | 12 |
| Quartz | 23 | 33 | 54 | 59 | 52 | 46 | 51 |
| Feldspar | 8 | 15 | 32 | 35 | 35 | 28 | 30 |
| Mica | 0 | 0 | Tr | 1 | 3 | 4 | 1 |
| Miscellaneous rocks and minerals‡ | 3 | Tr | Tr | 3 | 6 | 12 | 2 |
| Weathered particles | 3 | Tr | 1 | 1 | 4 | 10 | 2 |
| Graywacke, siltstone, and chert | 16 | 6 | 2 | -- | -- | -- | 2 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

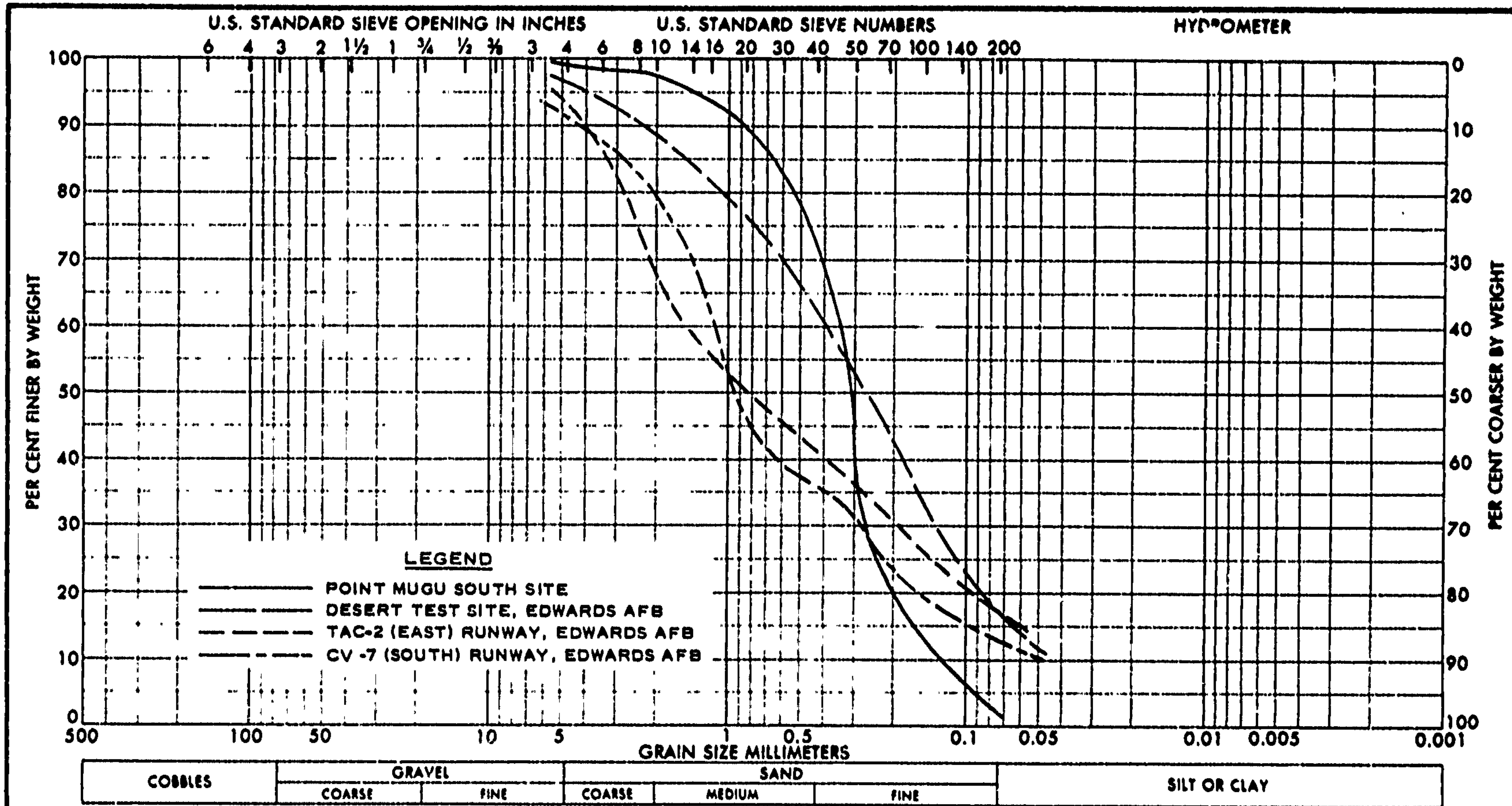
* Percentage is based on count of more than 300 particles in each sieve fraction.

** The No. 8 size was assumed to have the same composition as next smaller size for purposes of calculation.

† Analysis was made on particles passing No. 200 and retained on No. 400 sieve

†† Percentage is based on gradation of samples as received and on the distribution of constituents by sieve fractions shown at left above.

‡ Amphiboles are among the constituents of this class. The material finer than No. 200 includes some mica, minor 14-A clay, probably montmorillonite, and minor kaolin-group clays.




| SAMPLE NO | ELEV OR DEPTH | CLASSIFICATION | NAT W% | LL | PL | PI |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

GRADATION CURVES

POINT MUGU AND EDWARDS AFB
TEST SITES